NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

EFFECT OF OPTEMPO ON SHIP OPERATIONAL COSTS

by

Tadd H. Gorman

December, 2003

Thesis Advisor:	Kenneth Doerr
Second Reader:	Philip Candreva

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE December 2003	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE: Effect of OPTEMPO on Ship Operational Costs	**5. FUNDING NUMBERS**
6. AUTHOR: Tadd H. Gorman	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A	**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited	**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

The purpose of this study was to determine the relationship between operations tempo (OPTEMPO) and operational costs. This study was performed at the request and with the support of OPNAV N82, the Office of Budget (FMB). The goal of this project was to increase the flexibility, scalability, and justifiability of the analytical model used by FMB to budget for ship operations. This study provides a detailed description of the model including modifications made by the only other study of the FMB budgeting model. The core of the analysis centered around a regression of OPTEMPO and expenditure data. From the resultant regression equations, incremental costs of ship operations could be distilled. However, during the preliminary data validation, significant correlations were found only within the Arleigh Burke Destroyer Class of ship. These correlations were likely spurious and due to the large number of new commissionings within that class over the period of study. The lack of ability to define any relationship between OPTEMPO and expenditures is possibly due to complete expenditure of fund allocations regardless of actual costs.

14. SUBJECT TERMS Budget Allocation, Correlation, Cost Analysis, Cost Estimates, Forecasting, Navy, Naval Vessels, Operating and Maintenance Costs	**15. NUMBER OF PAGES** 127
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

EFFECT OF OPTEMPO ON SHIP OPERATIONAL COSTS

Tadd H. Gorman
Lieutenant, United States Navy
B.A. University of North Florida, 1996

Submitted in partial fulfillment of the
requirements for the degree of

MASTERS OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
December 2003

Author: ____________________________
Tadd H. Gorman

Approved by: ____________________________
Kenneth Doerr
Thesis Advisor

____
Philip Candreva
Second Reader

____
Joseph San Miguel
Academic Associate

____
Douglas A. Brook, Dean
Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

The purpose of this study was to determine the relationship between operations tempo (OPTEMPO) and operational costs. This study was performed at the request and with the support of OPNAV N82, the Office of Budget (FMB). The goal of this project was to increase the flexibility, scalability, and justifiability of the analytical model used by FMB to budget for ship operations. This study provides a detailed description of the model including modifications made by the only other study of the FMB budgeting model. The core of the analysis centered around a regression of OPTEMPO and expenditure data. From the resultant regression equations, incremental costs of ship operations could be distilled. However, during the preliminary data validation, significant correlations were found only within the Arleigh Burke Destroyer Class of ship. These correlations were likely spurious and due to the large number of new commissionings within that class over the period of study. The lack of ability to define any relationship between OPTEMPO and expenditures is possibly due to complete expenditure of fund allocations regardless of actual costs.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

Many thanks to my advisors for their boundless knowledge, kind patience, and adjacent offices. Most importantly, to my family who will never again have to hear the words “I have to do my thesis.”

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

This chapter briefly describes the budget office taxonomy and the stakeholders involved. It gives the relative size of the budget elements germane to this study, and the number and type of operational units funded. The general purpose of the study and the organization of the paper are also addressed.

A. BACKGROUND

Determining budget requirements for the U.S. Navy surface fleet is a daunting task. Just as with civilian businesses, there are many variables involved that make cost predictions tenuous at best. Some variables are impossible to predict such as contingency operations in any given year. However, in light of recent initiatives such as Sea Enterprise and the Department of Defense Planning, Programming, Budgeting and Execution (PPBE) system, it is increasingly more important to predict future cost more accurately, and analytically justify increases in program costs.

The Navy Operations and Maintenance (O&M) Budget is broken down into four Budget Activities – Operating Forces, Mobilization, Training and Recruiting, and Administration and Service-wide Activities. These activities are referred to by the numbers 1,2,3, and 4 respectively. The Activities are broken down into Activity Groups by general warfare areas – Air, Surface, Communications, etc, and have letter designations to identify them. For example, 1A would be Air Warfare related operations Budget Activities, 2B would be surface ship related reserve force Activities, and so on. A specific Budget Activity Group bears additional designations that further break down and compartmentalize budgeting and resource responsibilities into operational, safety, support, maintenance, and training cost categories.

The 1B1B Sub-Activity Group coordinates and develops a portion of surface ship operational force budgeting (determinable from the first two characters – 1B). This Sub-Activity Group specifically constructs "Mission and

Other Ship Costs". The following is official description of operations financed according the US Navy 2004 Biennial Presidential Budget Submission:

> This sub-activity group provides resources for all aspects of ship operations required to continuously deploy combat ready warships and supporting forces in support of national objectives. Programs supported include operating tempo (OPTEMPO), fleet and unit training, operational support such as command and control, pier side support and port services, organizational maintenance, and associated administrative & other support. (OMB, 2003)

In fiscal year 2002, the 1B1B sub-activity was responsible for approximately 2.5 billion dollars – that equates to thirty-two percent of the 1B Activity Group funding, twelve percent of Budget Activity 1 funding, and almost ten percent of overall Navy O&M funding. Tables 1 through 3 show the fiscal year 2002 breakdown.

Budget Activities	**$ in millions**
BA 1	$ 20,499
BA 2	$ 801
BA 3	$ 2,173
BA 4	$ 4,812

Table 1. FY02 Navy O&M Budget Broken Down By BA (Millions of $)

Activity Groups	**$ in millions**
1A	$ 5,554
1B	$ 7,864
1C	$ 2,170
1D	$ 1,305
1F	$ 2
Other	$ 3,605

Table 2. FY02 BA1 By Activity Groups (Millions of $)

Sub-Activities	$ in millions
1B1B	$ 2,501
1B2B	$ 493
1B3B	$ 391
1B4B	$ 3,143
1B5B	$ 1,336

Table 3. FY02 1B Sub-Activity Groups (Millions of $)

The 1B1B budget is further categorized into six major cost programs. Those costs programs are Fuel, OPTAR (Operating Target), Utilities, TAD (Temporary Additional Duty), Charter, and Combating Terrorism. The Fuel Program involves costs associated with the procurement, storage and distribution of the distillate fuels associated with fleet and ship operations. The OPTAR Program involves costs associated with unit level repair parts and consumable item purchases. The Utilities Program involves costs associated with birthing ships in port. TAD Program involves costs associated with unit level crew travel and training. Charter is a non-specific cost category that involves costs not associated with the other categories. Combating Terrorism has been recently added and involves costs associated with fighting terrorism. These costs associated with operating the fleet are shown in Table 4 and broken down by fiscal year as taken from the US Navy 2004 Biennial Presidential Budget Submission.

	2002	2003	2004	2005
CV/CVN	12	12	12	12
Surface Combatants	108	98	94	91
Amphibious	38	37	35	36
Fast Attack Sub	54	54	54	55
Ballistic Missile Sub	18	18	18	18
Logistic	33	33	33	34
Mine Warfare	11	11	11	11
Support	19	20	19	19
Patrol Coastals	-	13	13	-

Table 4. Ship Quantities Funded by Fiscal Year (OMB, 2003)

The office that assembles the navy budget submission is the Navy Office of Budget (FMB). N80 is the OPNAV Department that manages the budgeting process for the resource requirements determined by the requirement office, N76. The N82 office, within N8, contains the 1B1B Sub-Activity Group. Figure 1 shows the reporting responsibilities for the N8 Organization within the Office of the Chief of Naval Operations (OPNAV).

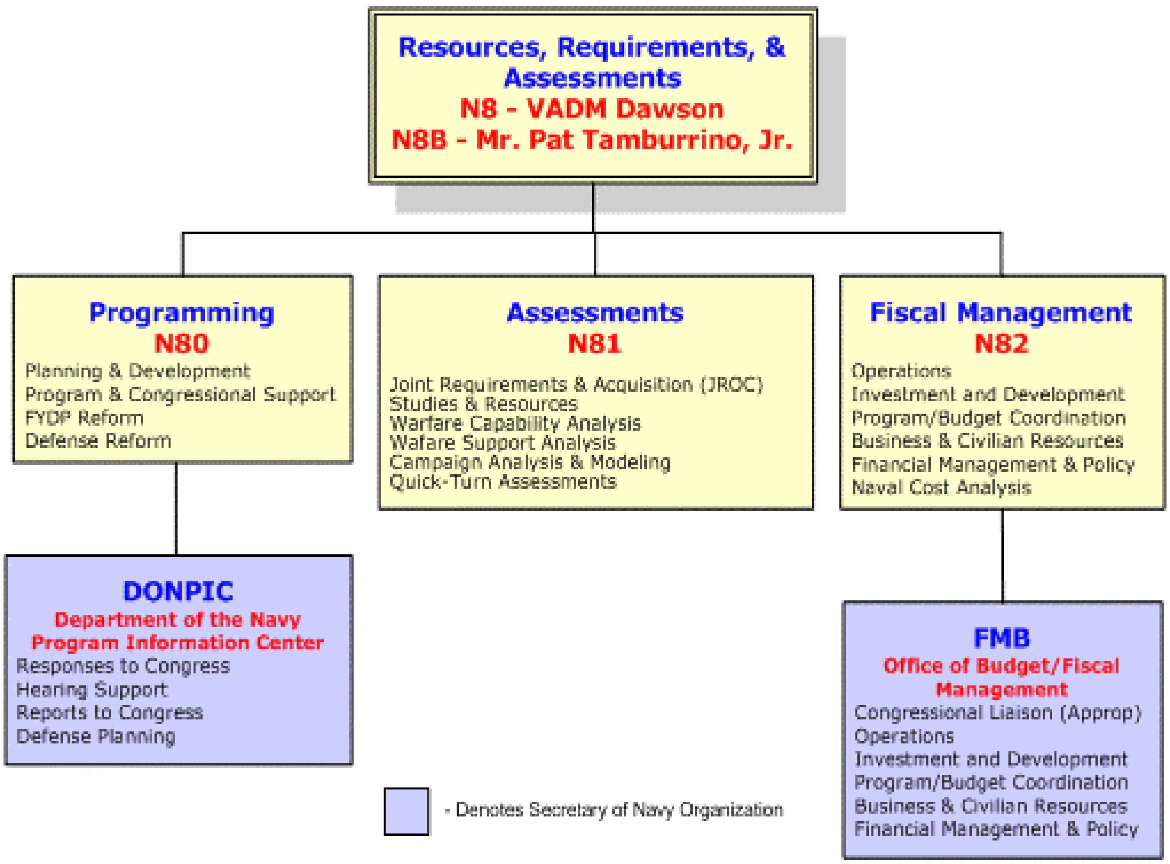

Figure 1. N8 Organization Chart (OPNAV, 2003)

B. PURPOSE OF STUDY

The Navy is in the process of a paradigm shift. Gone are the days of the Cold War, predictable threats, and routine deployment schedules. Since the terrorist attacks of September 11, 2001, the President has recognized new threat priorities in the National Security Strategy (NSS). The threat is amorphous and can exist anywhere even within the U.S. border. The Navy must move away

from powerful but cumbersome Battle Groups towards a lighter and more flexible response force capable of surging as required. With routine deployment packages and schedules, budgeting is simplified and changes in more predictable ways from year to year. With the change in US strategy, there is a necessary change in both force structure and force employment. These two changes have a certain impact on resource requirements. Determining what that impact is and how to plan for it is a budget concern. Discovering cost drivers can help create a more accurate picture of how future operations impact the budget. Understanding of those drivers can then be applied to determining incremental costs of additional or increased operations.

Previous budgets and the FY04 budget are based on the notion of a constant Operations Tempo (OPTEMPO). While this may have made sense as an average number in previous years, this may no longer be the case. Depending on fleet surge requirements and contingent operations, the Navy may need to anticipate a more variable number for days underway vice the current constant expectation of 54 days a quarter underway per deployed ship (OMB, 2003). In order to meet a potentially wider base of training requirements, a variable number of days underway while not deployed should be considered vice the current constant 28 days (OMB, 2003). Without a clear understanding of how these OPTEMPO changes affect costs, it is difficult to budget for incremental ships or days underway as OPTEMPO becomes a less predictable figure.

The focus of this study is to explore the relationship between (OPTEMPO) and costs since the number of days conducting operations away from homeport seems to be an obvious cost driver that would be easy to measure and incorporate into the budgeting process.

C. ORGANIZATION OF PAPER

Chapter II will consist of a literature review in which the generic budget models, Department of Defense budget guidance, and previous studies of OPTEMPO will be discussed. Chapter III will describe the budget model

currently used by N82 to get first estimate budget figures, the most recent model study results and the current model's strengths and weaknesses. Chapter IV will address this study's OPTEMPO analysis to include the data analyzed, methodology, and data cleansing. Chapter V will consist of the analysis results and interpretation in context of the budgeting and allocation processes. Chapter VI will conclude the study and offer suggestions for further study.

II. LITERATURE REVIEW

This chapter addresses general Department of Defense budget model purpose, usefulness, and requirements. The over arching guidance providing the framework for budgeting decisions will be briefly discussed, and the results and relevance of previous OPTEMPO studies will be examined as their conclusions support this study.

A. DEPARTMENT OF DEFENSE BUDGET MODELS

The Department of Defense (DoD) and, in particular, the Department of the Navy (DoN), uses analytical and numerical models to compute a baseline for projected budget estimates. With the trend in the DoD to streamline and validate the budget process, models that can be validated and periodically verified are required to demonstrate total funding needs beyond baseline or historical figures. Likewise, when a budget-submitting office wants to increase the baseline funding level of a program beyond inflation factors, justification must be made to Congress. A powerful form of justification is the output of a validated analytical model. Without an understanding of the cost drivers within the budget, it will be difficult to generate an accurate forecast of costs in an evolving and dynamic strategic environment.

B. DEPARTMENT OF DEFENSE BUDGET GUIDANCE

There are two major documents by which the Navy is guided in determining how resource requirements should be budgeted – the National Security Strategy (NSS) and the Defense Planning Guidance (DPG). These documents form the keystone of each service's strategies, and subsequently how they spend money. The NSS and DPG are worded in broad terms and generalities. This is to ensure that each service can define the concepts presented in these documents in terms of their own missions and capabilities.

The current version of the NSS was released in 2002, and it establishes a further differentiation between modern fighting forces executing contingent operations and yesterday's Cold War containment patrol-type operations. It consists of several chapters that address the following issues:

- Champion aspirations for human dignity;
- Strengthen alliances to defeat global terrorism and work to prevent attacks against us and our friends;
- Work with others to defuse regional conflicts;
- Prevent our enemies from threatening us, our allies, and our friends, with weapons of mass destruction;
- Ignite a new era of global economic growth through free markets and free trade;
- Expand the circle of development by opening societies and building the infrastructure of democracy;
- Develop agendas for cooperative action with other main centers of global power; and
- Transform America's national security institutions to meet the challenges and opportunities of the twenty-first century. (Bush, 2002)

Some of these have an obvious impact on DoD and Navy funding, and others may have an indirect effect. Either way, the Navy must make the correct budgeting decisions to support these issues and realize the President's goals, which can have varying degrees of impact on OPTEMPO. Therefore, it is imperative to have an efficient and flexible budgeting model capable of outputting reliable cost predictions based on anticipated operations.

The DPG is a classified document that reflects the Secretary of Defense's (SECDEF) interpretation of the DoD's role in achieving the goals set forth in the NSS. It establishes priorities for committing and programming resources. Navy budgeting organizations must use this information to program and budget money to meet the NSS. The DPG also includes strategies, objectives, and other major issues relevant to programming money for budgeting activities. The DPG is usually published annually at the beginning of the programming phase of PPBE. However, as an exception resulting from PPBE reform, it has not been updated

since the most recent NSS was issued. The DPG provides the overarching strategic framework for programming decisions (OPNAV, 2003). The DPG often proves to be evolutionary depending on the political environment, perceived threat, and the individual occupying the position of SECDEF. A more flexible budgeting process based on easily measurable variables, such as OPTEMPO, provides a much more malleable response in support of changes to the guidance explicit in the DPG.

The Chief of Naval Operations (CNO) has a vision to revolutionize the way the Navy supports operations. That vision is called Sea Power 21 and is articulated in the Naval Information Roundup (England, Clark, and Jones, 2003). Sea Power 21 is comprised of a strategic triad – Sea Strike, Sea Shield, and Sea Basing. This strategic triad is enabled by a subset of three supporting policies – Sea Warrior, Sea Trial and Sea Enterprise. The purpose of Sea Enterprise is to increase the efficiency of the business aspect of the Navy. Initiatives under Sea Enterprise include refining requirements, reinvesting capital, and improved organizational structures – all sound business practices previously given only minimal attention. In fact, applying best business practices to Navy financial decisions is one of the tenets of this initiative. Using easily measurable cost drivers to budget for and allocate costs is therefore congruent with Sea Enterprise, and all the concepts under Sea Enterprise are congruent with the resource allocation strategies outlined in the DPG. Furthermore, Sea Enterprise's concept of refining requirements speaks directly to a leaner and more efficient budgeting process, and such processes cannot be achieved without an understanding of how costs are affected.

C. SUMMARY OF PREVIOUS SHIP OPTEMPO STUDIES

Williams (1987) studied surface ship OPTAR obligation patterns and their dependency on operating schedules and other factors. The study only focused on unit level obligation patterns based on quarterly Type Commander (TYCOM) allocations. TYCOMs are responsible for the administrative aspects of ship operations. There are multiple TYCOMs – a TYCOM for each type of asset

(submarine, surface ship, air) and separate TYCOMs for the east and west coasts. TYCOMs receive quarterly allocations of budgeted money, and in turn, allocate that money to the ships under their cognizance. Each TYCOM uses their own system for allocating their resources. Using both parametric and non-parametric methods for analysis, Williams concluded there was no significant relationship between OPTAR spending patterns and operating schedules. The author offers several reasons for failure to find a significant relationship. One reason is the study focused on total OPTAR obligations not individual components of OPTAR, and significant trends in those components are blurred in an aggregate approach. Another reason is that the study was focused on TYCOM allocations to individual units, and the "use it or lose it" mentality of the quarterly allocations diluted any pattern in obligation rates. The current research addresses the former shortcoming by examining individual components of OPTAR and their relationship to OPTEMPO. The latter shortcoming remains problematic, and will be addressed at the end of the thesis when discussing conclusions and limitations.

Kuker and Hanson (1988) studied the feasibility of relating surface ship OPTAR obligation patterns to their operating schedules and TYCOM levels of allocation. The study found significant relationships between operating schedules and OPTAR obligation patterns of Belknap Class Cruisers and Knox Class Frigates. Regression analysis was done on these two classes of ships and equations were created that approximate the relationship. Although those classes of ships are no longer in commissioned service, a similar type analysis was attempted in this study at a Navy-wide vice TYCOM level.

Catalano (1988) studied OPTAR allocation patterns for surface ships in the Pacific Fleet. Regression analysis was conducted in order to create OPTAR allocation models for TYCOM staff comptrollers. Two successful models were completed for the Newport class LST and Spruance Class destroyer. The Spruance Class destroyer is included in this study, but the focus is in determining relationships between OPTEMPO and expenditures at the FMB level vice allocation models at the TYCOM level. However, since working allocation

models were developed at the TYCOM level, it was thought significant patterns may exist that can be modeled at the FMB level.

Ting (1993) studied TYCOM operating and support cost models for US naval ships. Through structural analysis, the study found a strong and quantifiable relationship between operating schedules and operating and support costs. The study also concluded that ship overhaul costs should be analyzed separately from other costs due to significant differences in cost calculations. Therefore, this study does not consider overhaul expenditures.

Hascall, Matthews, Gyarmati, Gantt, and Hajdu (2003) published an MBA professional report on an analysis of the 1B1B ship operations budget model. The study examined whether or not the model being used by N82 to predict OPTAR costs could be improved by substituting regression based cost estimates in lieu of the moving average method already in use. This was first study found to conduct this type of analysis at the Navy-wide level. The study was partially successful in that significant relationships could be established between some of the independent variables studied and obligation patterns. Regression based estimation techniques were incorporated into the budget model slightly increasing the model's effectiveness. Actual expenditure data has not become available since the conclusion of their report to validate its assertions and estimates of future costs.

D. FORECASTING MODELS

Methods of forecasting, considering budgeting is a method of forecasting, can be divided into two major categories. The first is Mathematical Forecasts. This is the direction the Navy is heading in determining and budgeting for resource requirements. It involves statistical or analytical decision models to aid management in making objective decisions based on a validated and proven process. Judgmental Forecasting involves a more intuitive approach to decision making. It is the sum of intangible or non-analytical processes such as

professional opinion. Figure 2 shows the two major groups of forecasting methods.

Forecasting Methods

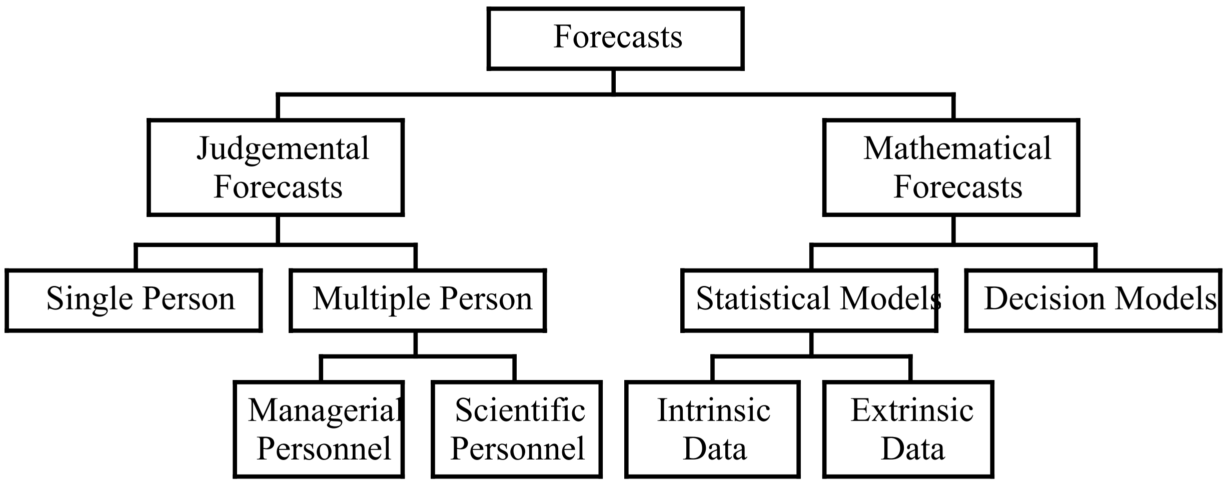

Figure 2. Forecasting Methods (Kuker and Hanson, 1988)

"Managerial judgment is personal intuition carried beyond a purely subjective vision of the future and includes historical trends, related events, the environment of the organization, and projections of future conditions" (Kuker and Hanson, 1988). Even though the process is subjective, "… it does not make it necessarily a less accurate method [of forecasting]" (Hosmer, 1982). Every budget is based on both mathematical and judgmental processes. However, the more mathematical the base of the budgeting process, the easier and more complete future analysis becomes as less explainable variation is introduced into the process. Mathematical models that are created to justify and rationalize a judgmental process can be misleading by producing analytically justifiable but inaccurate data. This study takes a mathematical look at possible relationships between the variables, but as it will be discussed in the conclusion, there may be a high degree of judgmental forecasting or mathematical justification of judgmental forecasting that occurs in the budgeting process complicating mathematical analysis.

III. SHIP OPERATIONS MODEL

This chapter will explain the workings of the model used to provide a first estimate of forecasted operational costs both in its original form, and with the modifications provided by the Hascall et al. study, as well as model strengths and weaknesses. The end of the chapter has a brief treatment on changes in the PPBS process.

A. ORIGINAL SHIP OPERATIONS MODEL DESCRIPTION

The Ship Operations Model is the mechanism by which budget cost estimations are produced. The purpose of this chapter is to demonstrate the complexity of the budgeting model used by N82, and to give a sense of rigidity in the process that could be alleviated by a clear understanding of operational cost drivers – OPTEMPO in particular. Although the model used to calculate the first estimate of the 1B1B budget is continuously tweaked, the basic mechanics remain the same. The model is contained within a massive Excel workbook that contains four different kinds of spreadsheets. There are input spreadsheets, calculation spreadsheets, summary spreadsheets, and informational spreadsheets. Figure 3 is an excerpt from the Hascall et al. project that demonstrates the complex arrangement and interaction of these spreadsheets.

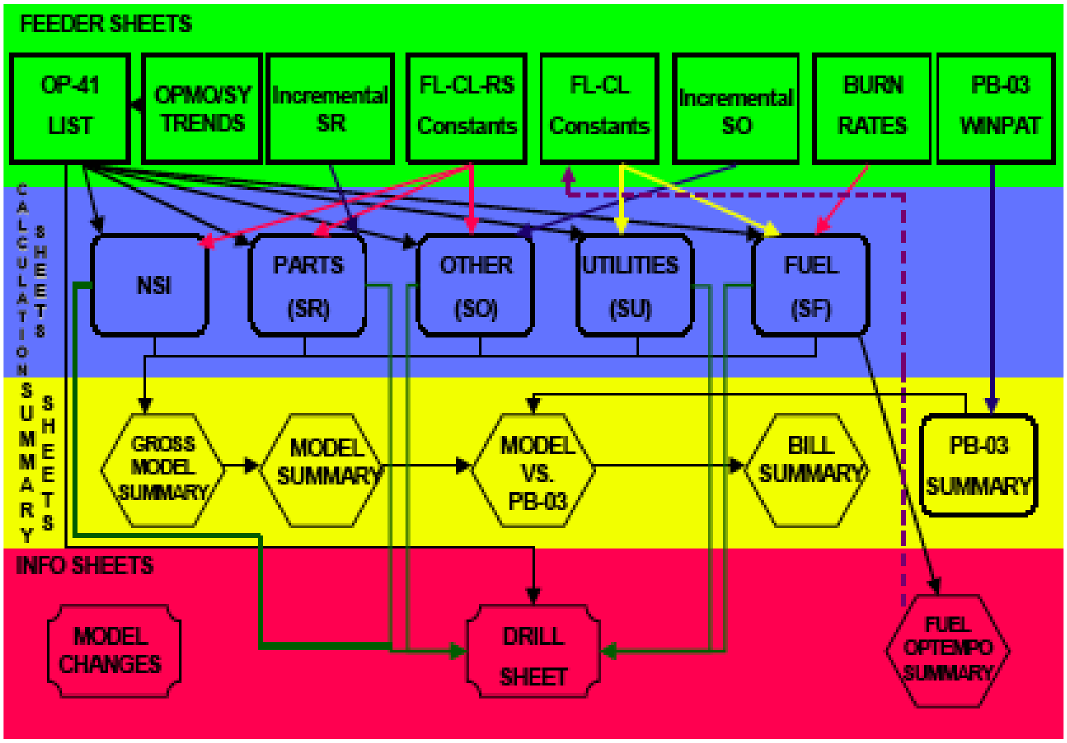

Figure 3. Model Spreadsheet Relationships

It is not necessary to understand the function of each one of the worksheets. However, the process flow is fairly simple. The feeder sheets provide the input data. This input is execution data that comes from the fleet through the Type Commanders and resource sponsors. These data are in the form of historical OPTEMPO (how much time the ship has spent underway in either a deployed or non-deployed status) and predicted future OPTEMPO. The data also include actual expenses incurred under the different cost categories. As mentioned in Chapter I, the costs are broken down into Fuel, OPTAR, Charter, Utilities, and Combating Terrorism. These costs are coded into the model by the abbreviations shown in Table 5.

Cost Code	Description
CT	Combating Terrorism
SF	Fuels
SR	Unit Level Repair Parts portion of OPTAR
SO	Other Consumables portion of OPTAR
SU	Utilities and Port Costs
NSI	No Special Interest

Table 5. Cost Code Descriptions

These input feeder spreadsheets also include necessary adjustment factors such as inflation factors, or factors that standardize prices across the Department of Defense. These factors are considered constants within the framework of the model.

The calculation spreadsheets calculate the forecasted budget amounts. A separate calculation spreadsheet exists for each cost code, and each spreadsheet uses a different algorithm for calculating estimated costs. The calculation of CT is exemplary of the basic algorithm, and it is calculated using a three-year moving average of historical costs as taken from the input spreadsheets. The result of the three-year average is then multiplied by price growth factors to determine forecasted costs. NSI and SO use the same process as CT. SR uses a similar process except it is adjusted with inputs from savings initiatives from the acquisitions process. SU uses a moving average of the last three years SU cost per operational month. That figure is then adjusted for inflation. The resultant is then multiplied by the total projected number of operational months. In order to determine SF requirements, the cost code is broken down into four categories: Deployed Underway, Deployed Not Underway (auxiliary steaming in port), Not Deployed Underway, and Not Deployed Not Underway. Fuel requirements are determined based on fuel burn rates during

these activities and the projected time in which ships are expected to be engaged in those activities. The number of barrels are summed and then multiplied by a standard price per barrel.

The summary spreadsheets are fed by the calculation spreadsheets. The data can be displayed on the summary spreadsheets in various viewer-friendly permutations of data categories. The summary spreadsheets contain the actual model output.

The information spreadsheets contain data that provide the model user information about the revision of the model being used. This spreadsheet also helps the model users and resource sponsors conduct budgeting drills. For a more detailed description of the model and model calculations, refer to Hascall et al. thesis, Chapter II.

B. CURRENT MODEL (WITH HASCALL ET AL. MODIFICATIONS)

When Hascall et al. conducted their study, comparisons were made between actual historical cost data, the estimate the original ship's model provided, and regression models built for cost codes SO and SR, and each class of ship. A determination was made whether of the regression or simple three-year average did a better job predicting the actual historical costs. In many cases, the regression did a better job than the three-year average at predicting the actual costs. Overall, the model's effectiveness was only increased by approximately six-percent when the regression equations were used in calculations where the regression equation was determined to be superior to the average. Tables 6 and 7 show the resulting calculation tables. In the regression equations, FY refers to fiscal year and UW refers to days underway. The first column of the tables show the ship class analyzed. The second column shows the percent difference between actual expenditures and the predicted cost estimates provided by the best method, shown in the third column. The equation that represents the best method is shown in the fourth column. Notice the most

frequently significant variable is fiscal year. This is most likely due to the fact that the data were not corrected for inflation.

SO	Best Value	Best Method	Best Method Equation
Atlantic Fleet			
AOE-1CL	10.10%	Original Model	3-year average
AOE-6CL	15.10%	Regression by Hull	SO=389210FY+2493TotalUW
MHC-51CL	30.80%	Regression by Hull Combined	SO=191960+46602FY
LHA-1CL	7.10%	Regression by Class	SO per ship=2457.30-118.07FY
LHD-1CL	9.40%	Regression by Class	SO per ship=2281.06+125.42
LPD-4CL	10.30%	Regression by Hull	SO=753710+49124FY
LSD-41CL	20.50%	Regression by Hull Combined	SO=384471+46986FY+370971PacFlt+1803TotalUW
CG-47CL	6.40%	Regression by Class	SO per ship=868.79+36.68FY
DDG-51CL	6.70%	Regression by Class	SO per ship=711.39+18.74FY
DD-963CL	6.00%	Regression by Class	SO per ship=754.38+18.24
FFG-7CL	3.70%	Regression by Class	SO per ship=617.03+24.25FY
ARS-50CL	7.00%	Regression by Class	SO per ship=469.82+45.26FY
Pacific Fleet			
AOE-1CL	16.87%	Original Model	3-year average
AOE-6CL	19.90%	Regression by Hull Combined	SO=230024+585647PacFlt+3912TotalUW
LHA-1CL	10.50%	Regression by Class	SO per ship=1442.21+184.48FY+12.84TotalUW
LHD-1CL	14.70%	Regression by Class Combined	SO per ship=2399.28-172.72FY+447.15PacFlt
LPD-4CL	7.30%	Regression by Class	SO per ship=1333.15-81.15FY
LSD-41CL	19.00%	Regression by Hull	SO=513838+3846TotalUW
CG-47CL	14.30%	Regression by Hull Combined	SO=519990+70221FY+244877PacFlt+1061TotalUW
DDG-51CL	20.80%	Regression by Hull	SO=126572+40860FY+14069TotalUW
DD-963CL	14.40%	Regression by Class Combined	SO per ship=876.43-42.34FY
FFG-7CL	10.60%	Regression by Class Combined	SO per ship=704.09+36.86FY
ARS-50CL	11.80%	Regression by Class Combined	SO per ship=473.43-46.69FY+231.91PacFlt

Table 6. SO Calculation Table

SR	Best Value	Best Method	Best Method Equation
Atlantic Fleet			
AOE-1CL	9.84%	Original Model	3-year average
AOE-6CL	12.60%	Regression by Hull	SR per ship=1667.02+92.30FY
MCM-1CL	13.37%	Original Model	3-year average
MHC-51CL	40.00%	Regression by Class Combined	SR=492140+164273FY
LHA-1CL	15.20%	Regression by Class Combined	SR per ship=2148.28+91.33FY
LHD-1CL	8.63%	Original Model	3-year average
LPD-4CL	10.74%	Original Model	3-year average
LSD-41CL	12.84%	Original Model	3-year average
CG-47CL	9.90%	Original Model	3-year average
DDG-51CL	8.90%	Regression by Class	SR per ship=1328-98FY
DD-963CL	4.40%	Regression by Class	SR per ship=1958.27+65.34FY
FFG-7CL	3.00%	Regression by Class	SR per ship=1450.98+43.07FY
ARS-50CL	11.90%	Regression by Hull	SR=414091+48712FY
Pacific Fleet			
AOE-1CL	19.60%	Regression by Hull Combined	SR=1582192+210046FY-446790PacFlt
AOE-6CL	14.70%	Regression by Hull Combined	SR=461317-290374PacFlt+15993TotalUW
LHA-1CL	14.40%	Regression by Class	SR per ship=2349.51+176.33FY
LHD-1CL	10.26%	Original Model	3-year average
LPD-4CL	11.66%	Original Model	3-year average
LSD-41CL	17.00%	Regression by Hull	SR=881305-56488FY
CG-47CL	9.10%	Original Model	3-year average
DDG-51CL	10.40%	Original Model	3-year average
DD-963CL	9.10%	Regression by Class	SR per ship=2033.56FY
FFG-7CL	4.90%	Regression by Class	SR per ship=1328.09+535FY
ARS-50CL	13.60%	Regression by Hull Combined	SR=414091+57674FY+252672PacFlt

Table 7. SR Calculation Table

C. MODEL STRENGTHS AND WEAKNESSES

The model, as modified by Hascall et al., showed a 6% increase in the variability of actual costs explained. By incorporating significant regression equations into the model, a better understanding of cost behavior is imparted since the cost variances associated with predicting budget costs are decreased. FMB has been fairly pleased over the past few years with the model's estimates. The operators that use the model to generate budget estimates are familiar with the model's operation. Use of regression equations in the model lends the ability to the model to estimate average incremental unit costs.

The model's functioning is difficult to understand without thorough study. Although the concept of what the model does is clear, how the model works is very esoteric (see Figure 3). On the other hand, certain aspects of the

methodology are overly simplistic. For example, the use of averages to predict future budget figures shows a lack of understanding of the independent variables that drive the costs and how they interact with the costs and each other. The model lacks the flexibility afforded by an understanding of these cost drivers – it cannot scale easily and is not dynamic with a changing operational environment.

D. CHANGES TO THE PPBS PROCESS

The PPBS (Planning, Programming and Budgeting System) process, the annual cycle by which the Navy plans for and submits budget inputs, is undergoing a metamorphosis that is supposed to streamline the process and make it more efficient. The name of the process has changed to PPBE (Planning Programming, Budgeting and Execution). The cycle has been flattened and is now a concurrent process in which programmed package requirements are determined, budgeted for and evaluated in concert. The process is now a biennial one in which the budget is built every other year and merely evaluated and adjusted in the off years. The most germane change to the process is the necessity for budgets with predictable costs to have models that are capable of being validated and routinely verified for accuracy (CNO, 2003).

THIS PAGE INTENTIONALLY LEFT BLANK

IV. DATA DESCRIPTION AND METHODOLOGY

This chapter describes the expenditure data and OPTEMPO data used in this analysis. The descriptions will include the form of the data as well as the immediate source. The latter half of the chapter is dedicated to the description of the methods used in the analysis of this study – data cleansing, regression models, correlation, and analysis of variance.

A. DATA DESCRIPTION

The analysis in this study was conducted on historical data. Data extracted from FMB documentation and the actual model contained both actual historical data and data estimates of previous years based on trend analysis. Every effort was made to ensure the data used in this study was actual and free of predicted data. Much of the data used in this study is the same data that was used in the Hascall et al. analysis. However, additional data was acquired and used since the focus of this study is different. For example, instead of using historical model estimates of costs, this study uses the actual expenditures.

1. Cost Data

Expenditures were used to analyze relationships between operations tempo and costs. Defense Financial and Accounting Service (DFAS), through FMB, provided the expenditure data used. It contained actual expenditure data for each cost code (as broken down by FMB) by Unit Identification Code (UIC). This is significant as it contains information down to the unit level, and the data can be analyzed at that level to determine unit level patterns in spending.

Additional expenditure data were harvested from the input feeder spreadsheet of the ship operations model, but this data was not used due to its suspect nature. The data in the feeder sheets does not necessarily represent actual expenditures since factors can be and frequently are adjusted during the year. As mentioned previously, the TYCOMs submit feeder sheet inputs, but the

TYCOMs do not necessarily use the same allocation systems for distributing O&M money to ships. As a result, a third party solution for the expenditure data was sought to mitigate these inconsistencies. DFAS records all expenditure data for every operational activity under the purview of this study, and had the expenditure data in electronic records for a period covering the last six years.

Whereas the expenditure data from DFAS covered a period of six years, the data from the FMB spreadsheets contained expenditure data for ten years. However, since the DFAS data contained information at the unit level, and the FMB data was consolidated to ship class, the DFAS data provided for the opportunity to validate the data between units. This allowed for a more powerful and thorough analysis. Using one source for expenditure data allowed the circumvention of some of the qualitative problems Hascall et al. had in their study (e.g., inconstant data availability among sources and inconsistencies in recording procedures).

Hascall et al. had to eliminate price growth factors from their study due to perturbations it caused in their regression analysis. This was not a factor in this study since the expenditure data used was not parsed from the model. All expenditure data is in actual dollars, and no effort was made adjust the figures for inflation. In general this may cause a problem because, for example, upward trends in nominal dollars may yield spurious correlations with upward trends in OPTEMPO, the inflation rate over the years in question was low enough, and the time horizon was short enough, that the use of nominal dollars was considered to be sufficiently accurate. All cost categories were analyzed with the exception of NSI. DFAS data could not be clearly traced back to this cost category. Although NSI is a catchall category, all miscellaneous expenses listed in the DFAS expenditure data could not be aggregated with confidence that it included all expenditures germane to this cost category. However, all the other cost categories were clearly labeled and discernable.

2. Employment Data

Operational tempo data used were from burn rates as recorded in the Navy Energy Usage Reporting System (NEURS). The data in this system provides information as to how much fuel is burned by a ship underway and inport as well as how many days the ship spent in each status. The actual employment of the ship was irrelevant in the data set as the ship was either in a deployed status or a non-deployed status. No effort was made to ascertain the theater of operation since Hascall et al. could find no significance in the differentiation. (Hascall et al., 2003) The data used was aggregated by ship class and was broken down into four categories – in a deployed status underway (DUW), in a deployed status not underway (DNUW), in a non-deployed status underway (NDUW), and in a non-deployed status not underway (NDNUW). Even if a ship is not in a deployed status, it may still be either conducting training that requires generators burning fuel pierside or the ship may be in a port other than its homeport operating their generators. Each category contains the total number of days spent in each category by all members of the ship class.

3. Ship Classes

The following ship classes were analyzed: All Carrier Classes, Ticonderoga Class Cruisers (CG-47), Arleigh Burke Class Destroyers (DDG-51), Oliver Hazard Perry Class Frigates (FFG-7), Spruance Class Destroyers (DD-963), Tarawa Class Amphibious Assault Ships (LHA-1), Austin Class Amphibious Ships (LPD-4), Whidbey Island Class Amphibious Ships (LSD-41), Wasp Class Amphibious Assault Ships (LHD-1), Sacramento and Supply Class Auxiliary Class Ships (AOE-1 and 6) combined. Mine Counter Measure and Mine Hunter class ships were not considered since enough data was not obtained to conduct analysis for this study. The above classes were chosen because they represent the major surface ship classes in the current fleet inventory.

B. METHODOLGY

The original conceptualization for this study involved exploring the relationships between expenditures, OPTEMPO and budget. That is, the amount of money budgeted to a ship, and the number of days underway both have an effect on how much a ship spends. The analysis of these relationships can produce an estimate of the costs associated with operating a ship at sea. This assumes that variations in OPTEMPO and budget are significant factors in explaining the variations in costs, and the amount a ship expends on a particular cost category is equal to the cost of operations associated with that category.

The central idea was to determine the effect of OPTEMPO on expenditures controlling for budget in order to divorce the effect of budget on costs and answer the central question of this study: What is the effect of OPTMEPO on operational costs. Controlling for budget proved too difficult to operationalize in this study because the data for the amount budgeted could not be found in a form comparable with the rest of the data. Since the model used by FMB produces a first estimate of the amounts for the Navy budget submission, the numbers FMB produces from their model must endure many machinations before the final budget number is reached. This is where the judgmental processes mentioned in Chapter II probably have their main effect. When the budget submission is made, the numbers are no longer in the form of the cost categories the 1B1B budget model uses. Therefore, it was not possible, with the data available in this study, to trace those figures back through those judgmental machinations to arrive at final budget figures in a comparable form to the ones used for expenditures. Therefore, this study focused solely on the relationship between OPTEMPO and expenditures without regard to budget.

1. Data Extraction

The expenditure data received was not in a form suitable to this analysis. The data files consisted of almost 10,000 records spanning over a dozen spreadsheets. The data was also listed by UIC, so it was difficult to determine which ship corresponded to the related expenditure data. There was a UIC key

included in the spreadsheet, but there were inconsistencies, missing entries and duplicate entries in the key. Once the UIC key was properly updated from current DFAS records, a program had to be written to scan the 10,000 records of data and insert the appropriate ship name into the data record. Once the ship names were inserted into the data records, another program was written to harvest and collate the expenditure by ship class, UIC (within ship class), and associated expenditures. The results of the program were check to verify proper execution.

2. Estimates of the Effect of OPTEMPO on Cost

Regression analysis constitutes the keystone of this study. The ultimate goal is to be able to explain how much to budget based on OPTEMPO. Through regression, an incremental relationship can be built to determine how much extra the nth day of operations of a certain class of ship will cost. This technique involves finding an equation for a line with cost as the dependent variable and OPTEMPO and budget as independent variables. The following equation is the general form for this line:

$$Cost = \beta_o + \beta_1 Budget + \beta_2 DUW + \beta_3 NDUW$$

Form the perspective of N82, the sponsor of this study, the relationship is more appropriately written in the following form, where the cost variable is in terms of the preceding fiscal year:

$$Budget_{FY} = \beta_o + \beta_1 Cost_{FY-1} + \beta_2 DUW + \beta_3 NDUW$$

However, in this study, since budget data was not obtained, the following equation demonstrates the portion of the relationship examined:

$$Cost = \beta_o + \beta_1 DUW + \beta_2 NDUW$$

This line will have the property that the sum of the squares of the distances from each datum point to the line is minimized. Each one of the coefficients represents the incremental costs per ship class associated with each

related OPTEMPO variable. If the regression is statistically significant, then the relationship uncovered in the regression can be interpreted as providing a meaningful explanation of the variation in the cost data, in other words, the coefficients for the independent variables can be interpreted as the incremental cost of one additional day underway. If the regression is not significant, then OPTEMPO data cannot be said to provide a meaningful explanation of the variation in the cost data and the coefficients are irrelevant.

3. Preliminary Investigation of Relationships Between OPTEMPO and Cost Variables

As a preliminary step, correlations were run for each combination of ship class / cost category and OPTEMPO category. Correlations can be easily completed, and they provide descriptive information about the underlying relationships between variables. If no correlation exists, then there is no need to run a regression because no relationship exists. The Correlation Coefficient is a ratio of the covariance and the product of the standard deviations of the groups. The results are a number between -1 and +1. A +1 indicates the groups have a perfect proportional relationship, that is, each varies exactly as the other. A -1 indicates a perfect inversely proportional relationship, that is, each is the perfect inverse of the other. Any number between -1 and +1 indicate varying degrees of these relationships. A zero indicates no linear relationship is present in the data.

4. The Validity of Aggregating the Data Across UIC

Since the expenditure data obtained is at the unit level, and the OPTEMPO data is at the ship class level, the expenditure data must be aggregated. However, this aggregation requires the assumption that there are no differences in expenditures at the ship level. Therefore, a validation must be done to ensure that this is not an erroneous assumption. ANOVA was used on the expenditure data to test for differences in spending patterns between individual units and between classes of ships. ANOVA provides a way of testing

multiple means for significant differences through a comparison the variation within and between multiple means. The following hypothesis is tested

H_0: $\mu_1 = \mu_2 = \cdots = \mu_n$

H_a: Not all population means are equal

In the case of the ANOVA, if statistical significance is reached, it means the rejection of the idea that all the populations are the same and there is at least one that is significantly different. So, groups of observations or "treatments" are analyzed to determine if there is a significant difference between treatments. In the ANOVAs run in this study, the UICs were treated as the treatments with each year as an observation within each treatment. The ratio of the two variances creates an F Distribution Statistic from which a p-value is calculated. The p-value can be interpreted as the probability an error would be made if the null hypothesis were rejected. A large p-value implies that there is no significant statistical difference between the treatments. For the purposes of this study, all significance tests are done for an alpha value of .05. However, p-values will be given so that the reader may judge the level of significance of a test for themselves.

THIS PAGE INTENTIONALLY LEFT BLANK

V. DATA ANALYSIS

This chapter contains the core analysis of this study. The results of the ANOVA conducted to validate the necessary data aggregation, as well as the preliminary correlation analysis will be presented and discussed. The correlations indicated that the intended regression analysis would only be useful on the DDG class. However, even in the DDG data, there is reason to suspect that the correlations obtained are spurious. Hence, there was no value in conducting regression analysis on this data set.

A. THE VALIDITY OF AGGREGATING THE DATA ACROSS UIC

The data was broken down by ship class and cost code. A table was created for each ship class / cost code combination (a total of 36 tables). The table was arranged by fiscal year and by UIC. Table 8, below, is an example of one of the tables analyzed.

UIC/Year	20633	20725	20748	20632	20550
1997	$1,568,475.70	$1,696,828.33	$1,757,693.59	$1,732,089.06	$1,806,403.92
1998	$1,841,820.19	$1,859,977.56	$1,672,192.65	$1,839,401.13	$2,382,670.68
1999	$2,084,813.23	$1,559,392.21	$1,742,635.59	$1,618,169.60	$1,858,577.24
2000	$2,584,049.13	$1,965,303.96	$1,186,024.72	$2,131,173.12	$3,186,780.47
2001	$1,772,045.91	$2,427,124.03	$3,363,282.91	$1,547,163.98	$1,872,693.86
2002	$2,911,069.98	$5,804,068.71	$1,489,532.74	$3,257,413.16	$1,457,276.84

Table 8. UIC Breakdown Table for LHA/SR

The results of the tests showed a significant difference between the units in some of the ship class / cost code categories. Table 9 delineates the results of the initial ANOVAs. The degrees of freedom (df) for each class of ship are indicated under the ship class. For each ship class / cost code combination, the F-statistic is given over the p-value. Combinations determined to be significant are highlighted.

		CT	SF	SO	SR	SU
CV	*F*	0.599815330	12.4835090	3.819846568	2.247517288	3.503846607
77 df	*p*	0.834479831	0.0000000	0.000207705	0.019005574	0.000508342
CG	*F*	0.881068577	0.4812533	1.231996015	3.488178515	1.498642857
137 df	*p*	0.618926359	0.9749150	0.235639304	0.000006450	0.087902938
DDG	*F*	0.701871346	2.5918752	7.583004514	8.995458608	1.077744853
215 df	*p*	0.892254085	0.0000233	0.000000000	0.000000000	0.364322262
FFG	*F*	0.797870105	0.8910133	3.819417855	4.534032535	0.797870105
161 df	*p*	0.743773736	0.6201626	0.000000167	0.000000003	0.743773736
DD	*F*	0.804616799	0.4614440	2.285080593	1.811896015	1.318824442
125 df	*p*	0.702905330	0.9750690	0.003678424	0.028296175	0.183750589
LHA	*F*	0.838104002	0.4199390	2.241644445	0.457212194	1.389723233
29 df	*p*	0.514017066	0.7926862	0.093228543	0.766278897	0.266126368
LPD	*F*	0.889460289	0.1643475	1.662216334	0.275403965	1.957126262
65 df	*p*	0.548641394	0.9979979	0.113609543	0.984137579	0.056511658
LSD	*F*	0.958161629	2.3698974	1.567441392	2.422579535	0.924906414
89 df	*p*	0.503177512	0.0087514	0.108750858	0.007360976	0.536620973
LHD	*F*	0.816718648	2.2867268	5.722298580	4.369713974	2.317844544
41 df	*p*	0.564394835	0.0574949	0.000314801	0.002151165	0.054629933
AOE	*F*	0.648405550	0.5593736	1.660771115	4.512587021	0.971319316
41 df	*p*	0.690997497	0.7594178	0.159995952	0.001741400	0.458895275

Table 9. Initial ANOVA Results

It raised concern that so many of the ship class / cost code categories demonstrated significantly different spending patterns within ship class. This implied that the ships within these categories could not be referred to interchangeably. The data was scrutinized and each one of these discrepancies was graphed in order to determine the root causes and to identify any outliers. All UICs' expenditures were graphed by year on one graph in order to determine any data patterns. As an example, Figures 4 through 6 are graphs of the DDG discrepancies – significant ANOVA's. Each line represents one UIC.

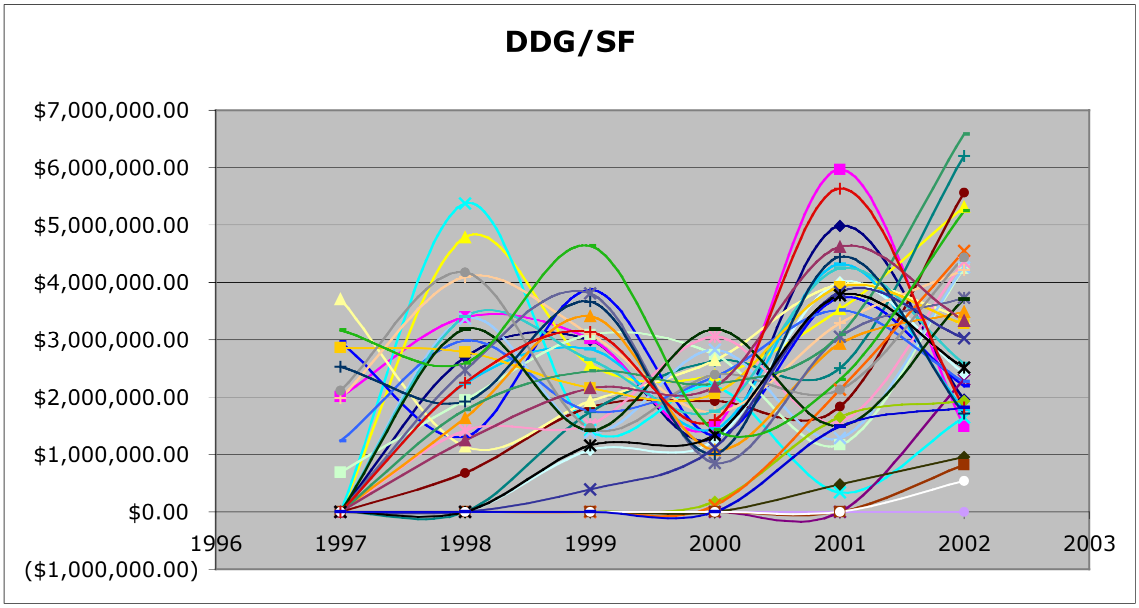

Figure 4. DDG SF Expenditures by Year

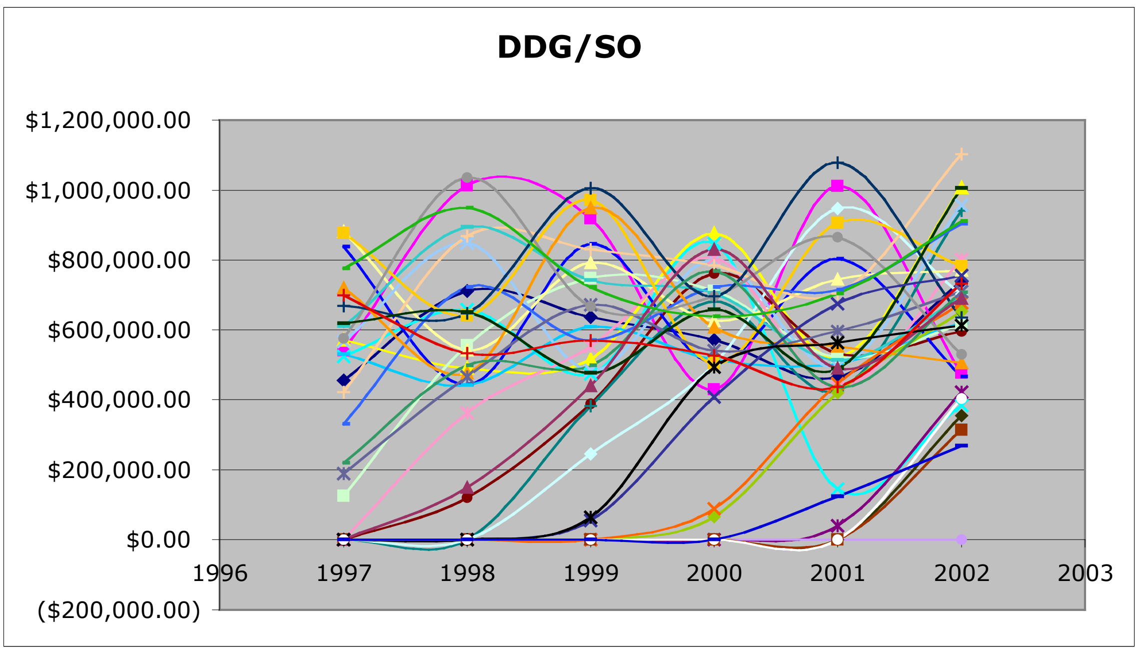

Figure 5. DDG SO Expenditures by Year

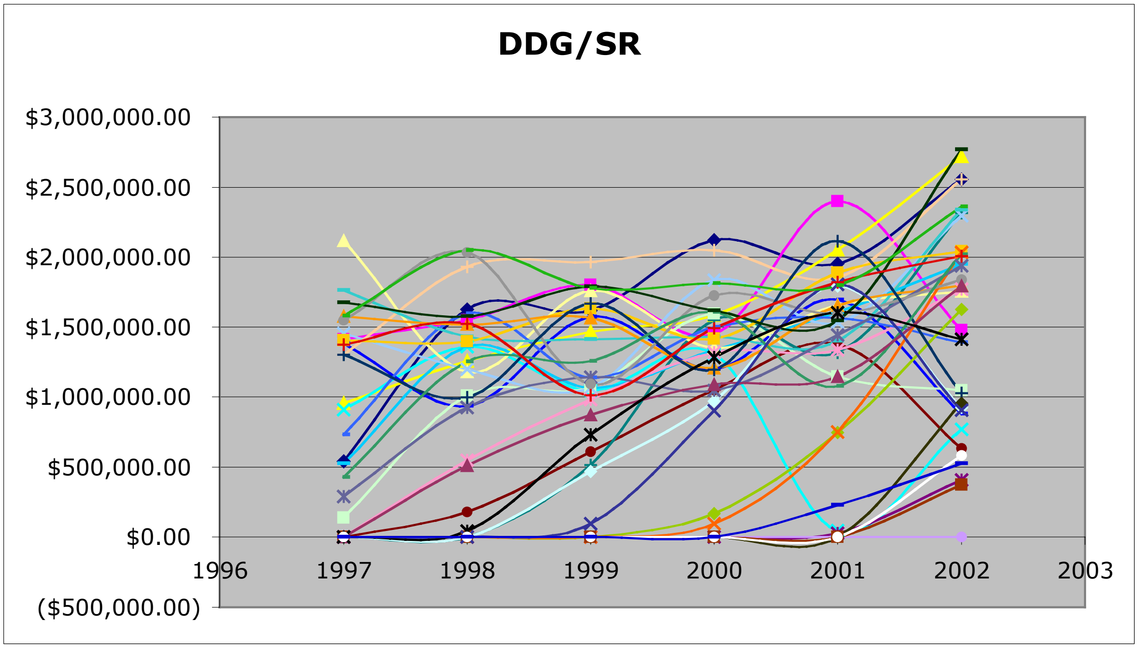

Figure 6. DDG SR Expenditures by Year

A clear pattern emerges in what corresponds to newly commissioned ships. There is a gradual ramping up of expenditures a ship's first year in service. To simplify the issue, those years having expenditures that correspond to fractional ship years were removed from the data set. Figures 7 through 9 show how the same data set looked after the removal of fractional year expenditures.

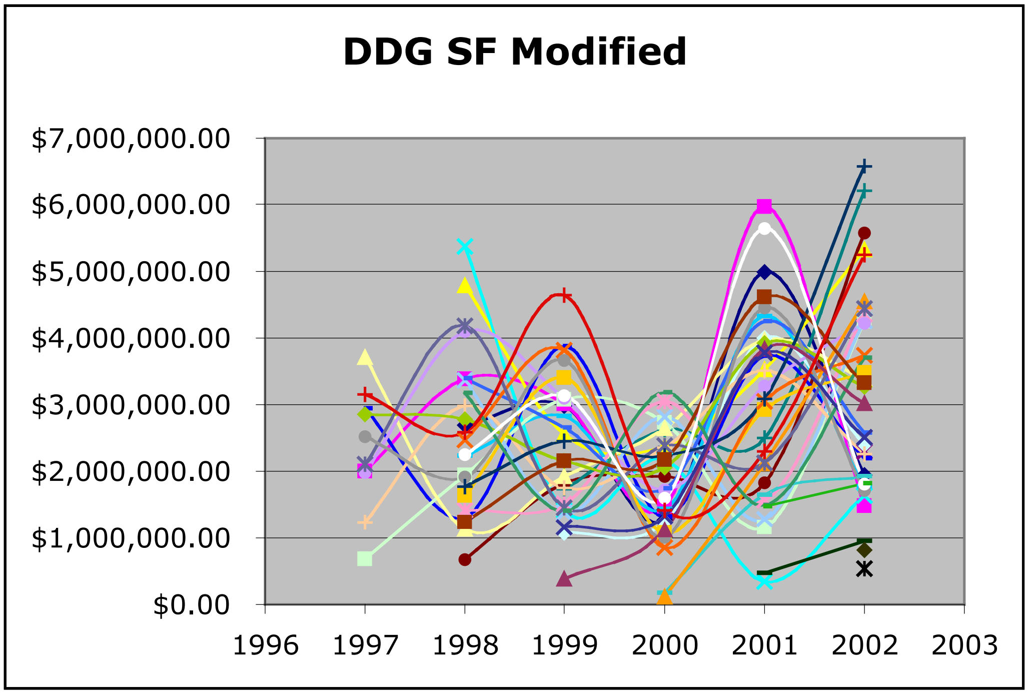

Figure 7. DDG SF Model After Cleansing

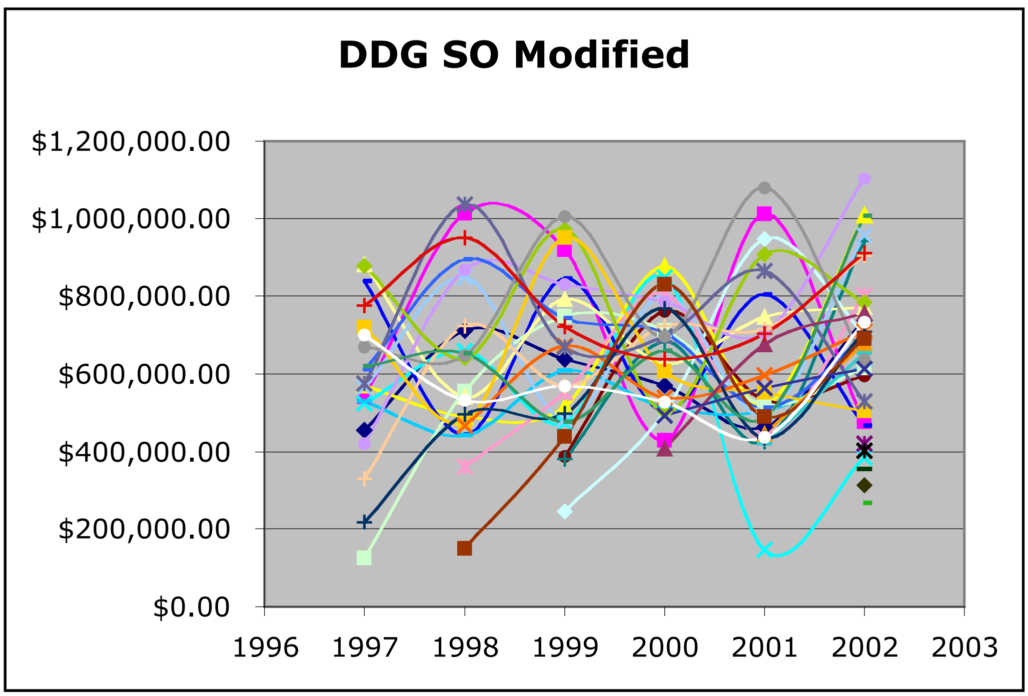

Figure 8. DDG SO After Data Cleansing

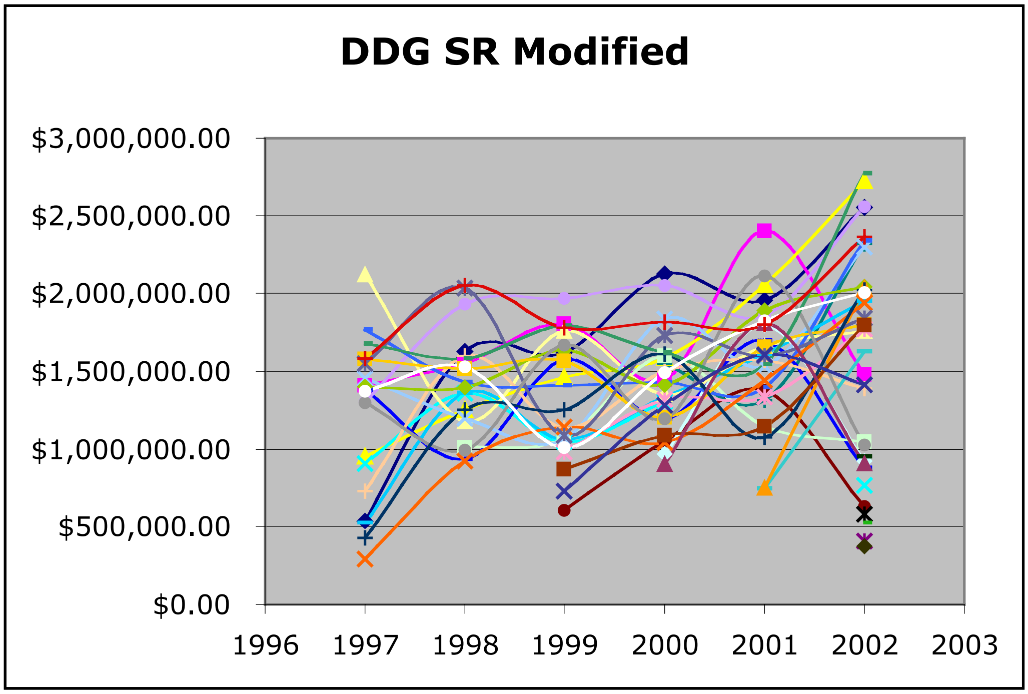

Figure 9. DDG SR After Data Cleansing

Notice that the data still contain some odd points that are off the general expenditure braid. These data are within three standard deviations of the mean and have no logical reason to be excluded from the study. Fortunately, when the ANOVA was run on the modified data, the significance between DDG ship classes disappeared. Table 10 shows the ANOVA result following the data cleansing. It is in the same format as Table 9.

		CT	SF	SO	SR	SU
CV	*F*	0.599815330	17.248459847	4.694996327	0.489442461	1.784273532
77 df	*p*	0.834479831	0.000000000	0.000049345	0.872448841	0.080401213
CG	*F*	0.881068577	0.481253332	1.231996015	0.956317675	1.498642857
137 df	*p*	0.618926359	0.974914965	0.235639304	0.523920921	0.087902938
DDG	*F*	0.701871346	0.693398196	1.320904891	1.320904891	1.077744853
215 df	*p*	0.892254085	0.891272936	0.136813533	0.136813533	0.364322262
FFG	*F*	0.797870105	0.891013294	1.531058475	0.949078614	0.797870105
161 df	*p*	0.743773736	0.620162611	0.066719408	0.539021324	0.743773736
DD	*F*	0.804616799	0.461444044	1.659116161	1.143663548	1.318824442
125 df	*p*	0.702905330	0.975068968	0.054180863	0.319339996	0.183750589
LHA	*F*	0.838104002	0.419939017	2.241644445	0.457212194	1.389723233
29 df	*p*	0.514017066	0.792686246	0.093228543	0.766278897	0.266126368
LPD	*F*	0.889460289	0.164347491	1.662216334	0.275403965	1.957126262
65 df	*p*	0.548641394	0.997997892	0.113609543	0.984137579	0.056511658
LSD	*F*	0.958161629	0.940335082	1.567441392	0.914759445	0.924906414
89 df	*p*	0.503177512	0.522306093	0.108750858	0.547469895	0.536620973
LHD	*F*	0.816718648	2.286726780	1.514794890	1.541027712	2.317844544
41 df	*p*	0.564394835	0.057494932	0.212582055	0.204396579	0.054629933
AOE	*F*	0.648405550	0.559373640	1.660771115	1.395158536	0.971319316
41 df	*p*	0.690997497	0.759417763	0.159995952	0.252587179	0.458895275

Table 10. ANOVA Results Following Data Cleansing

This process was repeated with all ships commissioned during period of study, but there were other problems with the data. As with the commissioning of ships and fractional ship years disturbing the data, so did decommissionings. Figure 10 shows an example from the Spruance Class Destroyers (DD-963).

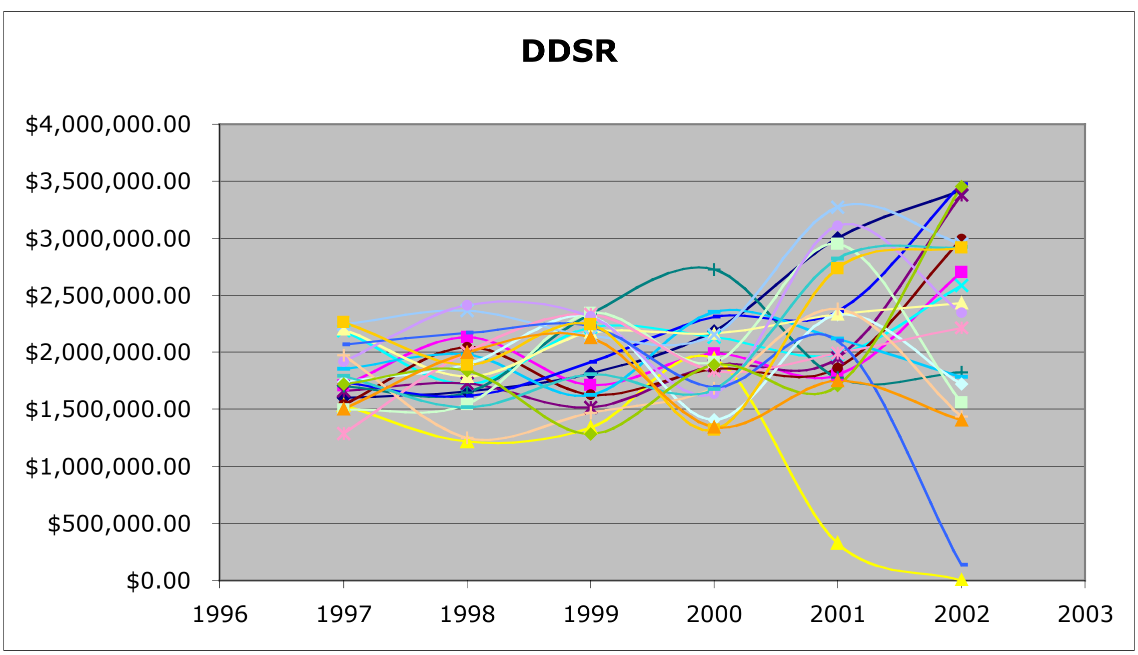

Figure 10. DD SR Expenditures by Year

Predictably, the ANOVA analysis for this ship class / cost code showed there to be significant differences between ship's expenditures. As with the newly commissioned ships, the fractional years of decommissioning ships were removed from the data set. The result is shown in Figure 11.

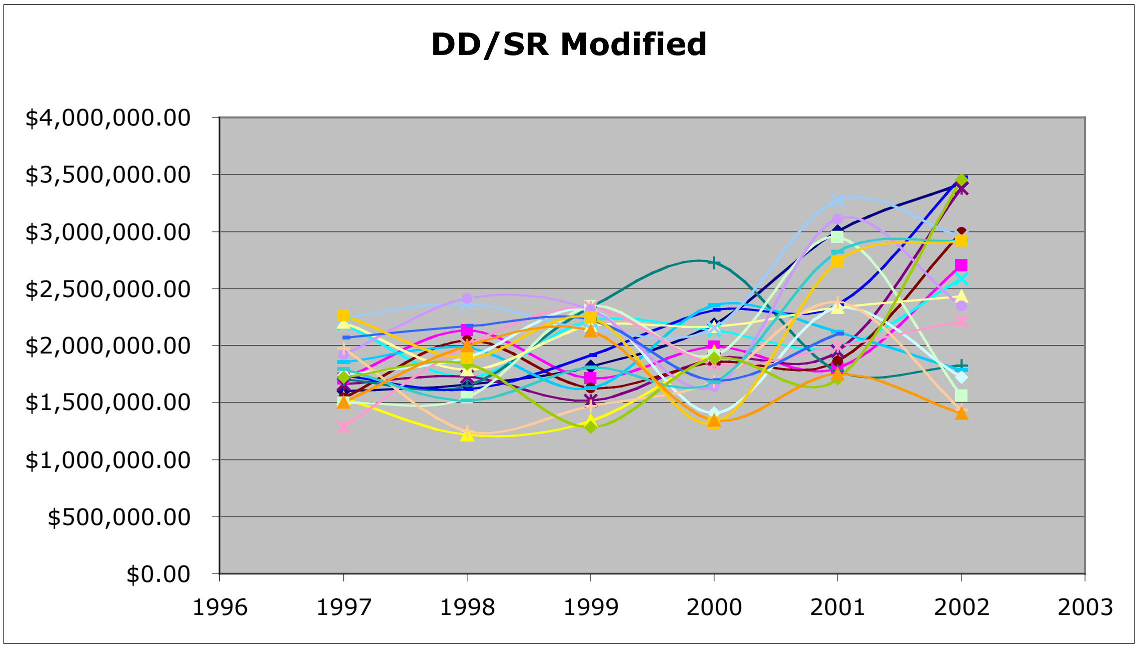

Figure 11. DD SR After Data Modification

After the fractional year data was removed, ANOVA was run on the remaining data, and there were no significant differences between ships.

The final problem encountered with the data set was there were several data points that were zero or negative. These represented a relatively few number of data points and were removed from the data set. Following the data clean up, all ship class and cost code combinations lost their significant differences except for the carriers.

Since the carriers retained their significant differences after the data modification, they were excluded from the remainder of the study. The fact that they retained their differences implies that analysis cannot be done on carrier expenditures in aggregate as a ship class. This was not completely unexpected

since there are only a few carriers, several hull designs, and wide variance of expenditures.

Appendix A contains complete initial ANOVA results. Appendix B contains all graphs of initially significant data of ship class / cost code by year. Appendix C contains all graphs of modified data of ship class / cost code by year. Appendix D contains complete ANOVA results of the modified data.

B. PRELIMINARY INVESTIGATION OF RELATIONSHIPS BETWEEN OPTEMPO AND COST VARIABLES

After it was determined that there were no statistical differences in expenditures within ship class / cost code categories, the expenditure data was summed by ship class within each cost category. The expenditures were graphed. Figures 12 through 15 show the DDG consolidated expenditure graphs. The ordinate of each graph is in thousand dollar units.

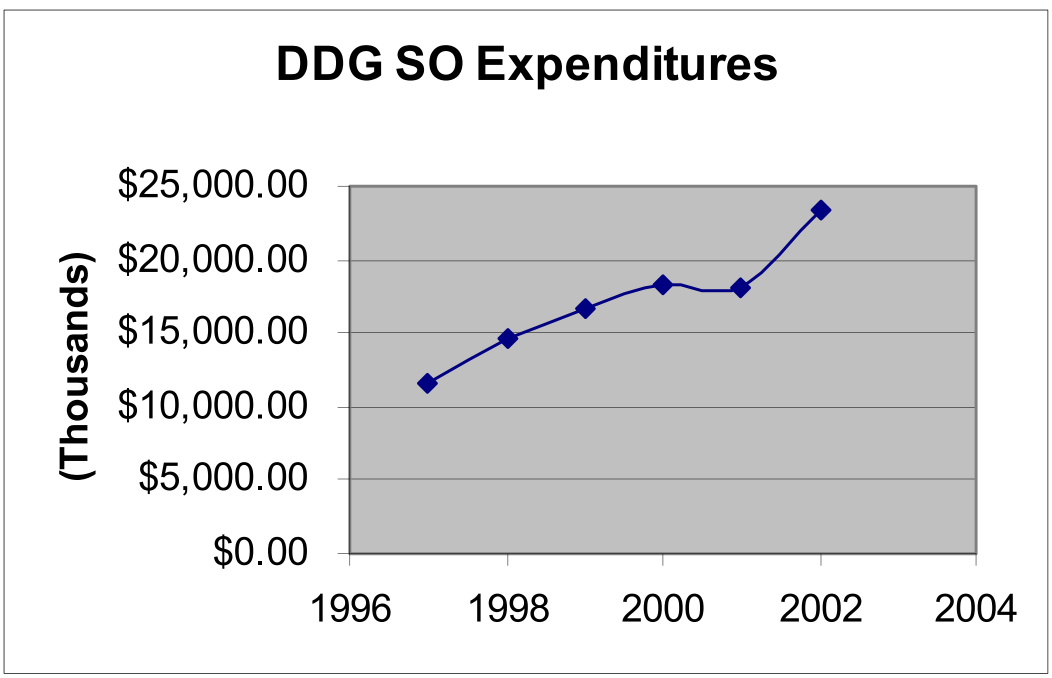

Figure 12. DDG SO Expenditures

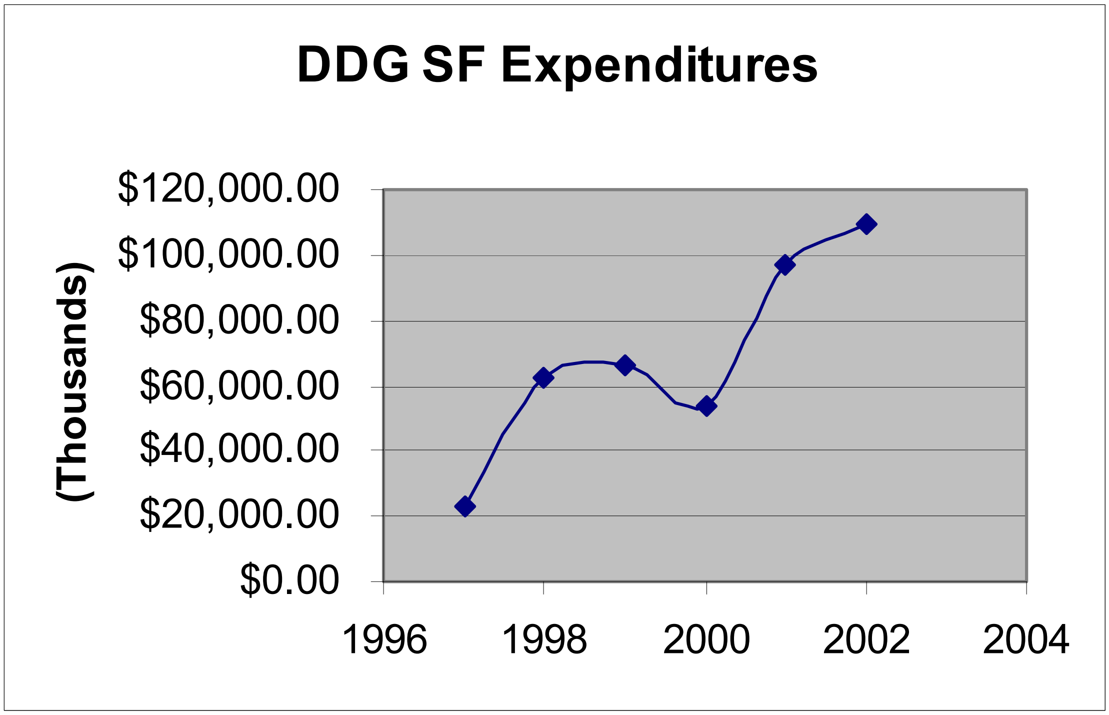

Figure 13. DDG SF Expenditures

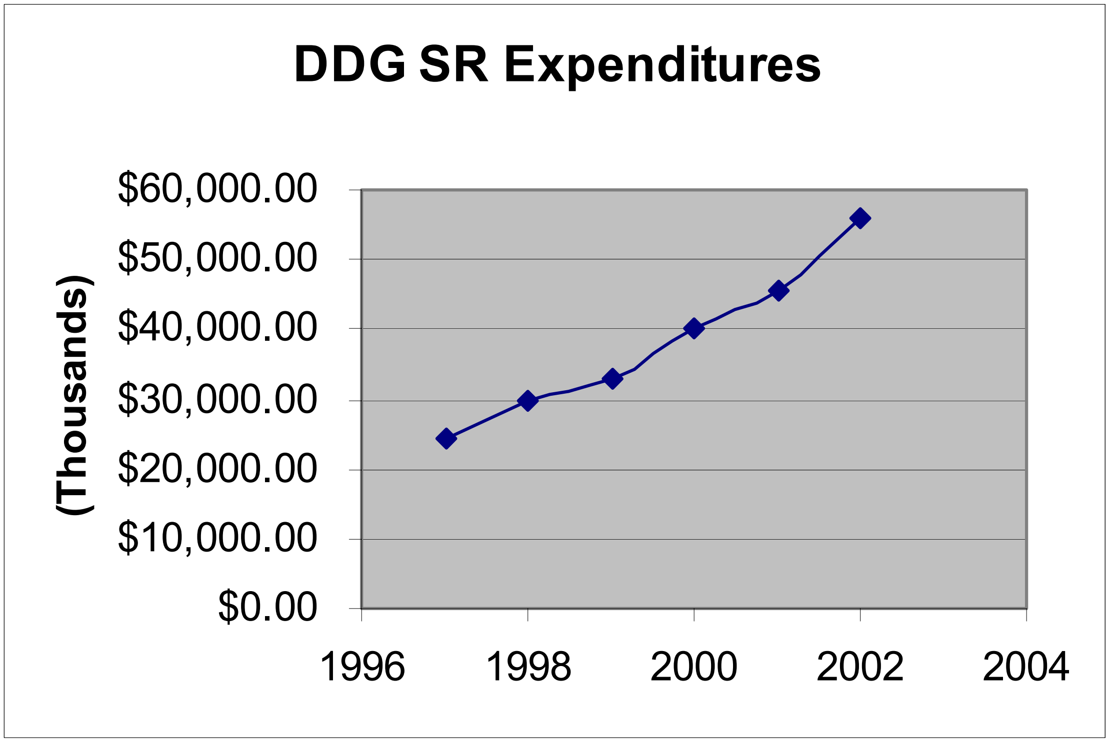

Figure 14. DDG SR Expenditures

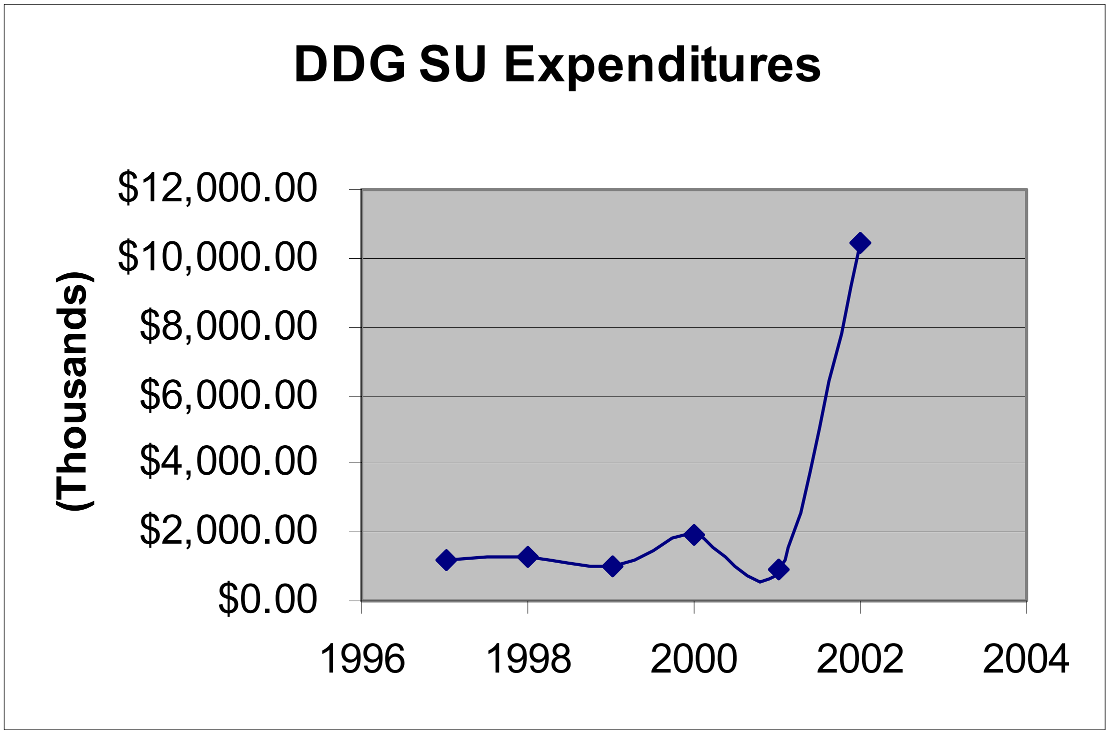

Figure 15. DDG SU Expenditures

Expenditure graphs for all ship class / cost code are in Appendix E.

The OPTEMPO data was divided into DUW, DNUW, NDUW, and NDNUW. As mentioned in Chapter IV, this data was only available by ship class. Table 11 shows this aggregate data for the DDG in days, and Figure 16 shows this data graphically.

DDG	DUW	DNUW	NDUW	NDNUW
1997	2503.1	959.8	1232.7	459.7
1998	2587.3	995.4	1274.2	475.5
1999	2850.8	1101.0	1404.0	524.3
2000	2733.6	1060.8	1346.4	503.2
2001	3227.2	1252.3	1589.5	594.1
2002	3563.3	1382.8	1755.1	655.9

Table 11. DDG OPTEMPO Data (aggregate days / year)

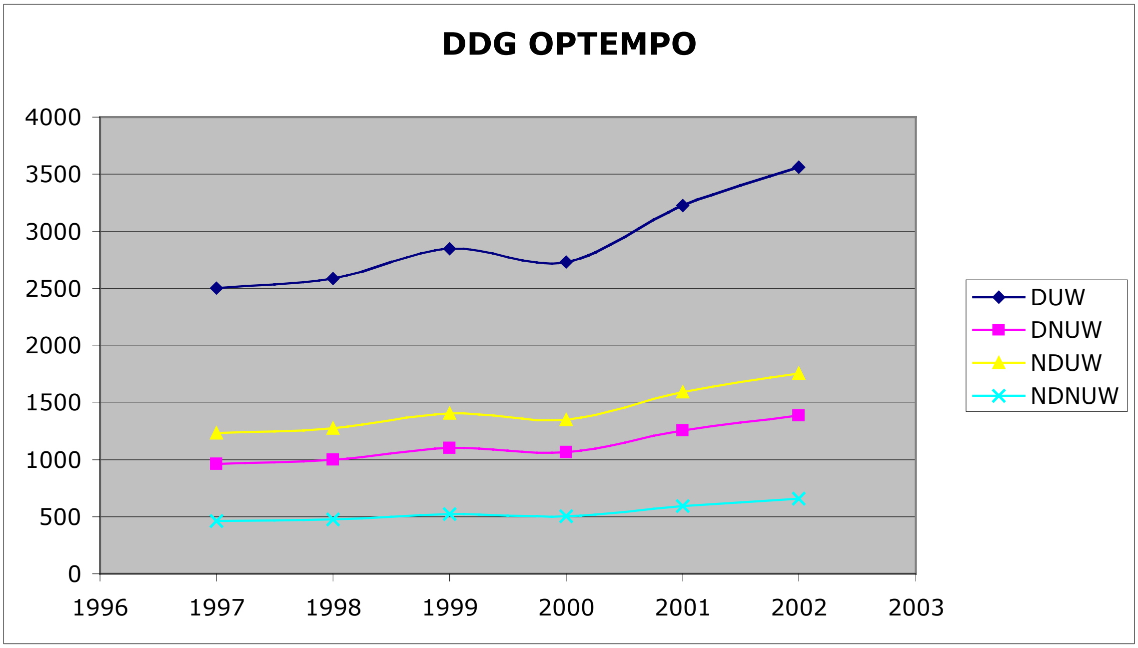

Figure 16. DDG OPTEMPO Graph

A strong visual correlation can be made between Figures 12 through 15 and Figure 16. An example is shown in Figure 17 where the total yearly expenditures are graphed against DUW days. However, this was not the case for all ship class / cost code categories, and a strong visual correlation does not necessarily translate to a statistically significant correlation.

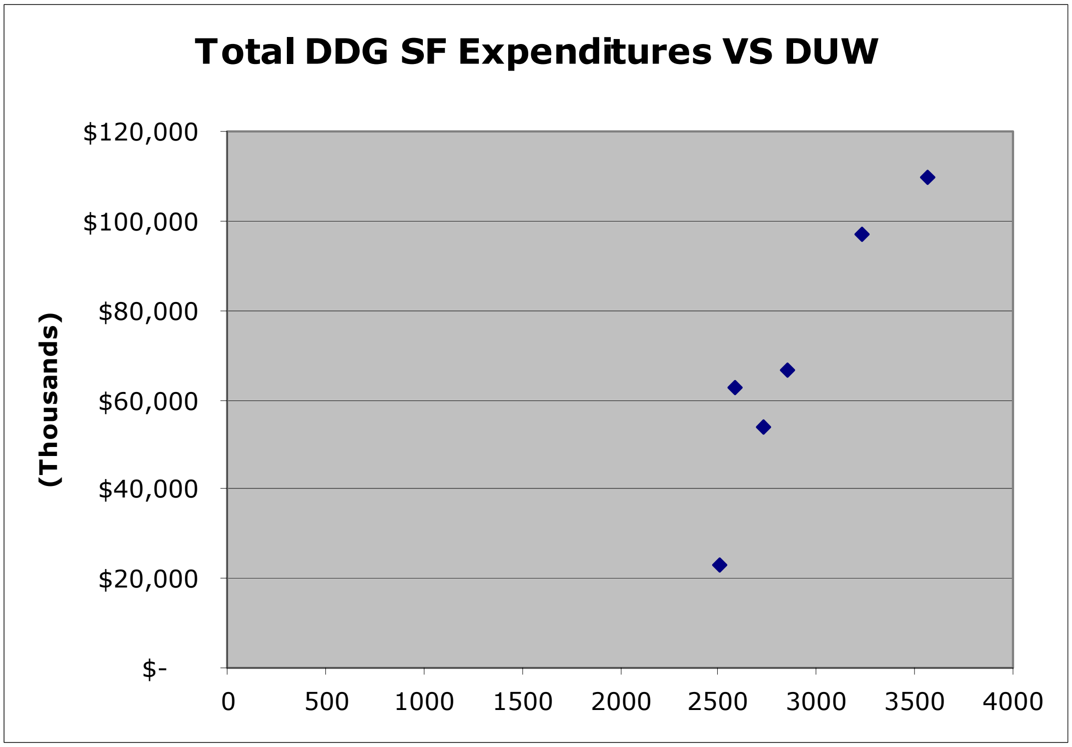

Figure 17. DDG Total SF Expenditures vs. DUW

Correlations for all ship class / cost codes with OPTMEPO categories are in Appendix F. Since the sample size is restricted to six in each category, a correlation coefficient of at least .90 is required to demonstrate a significant relationship. Of course, this is a serious limitation to this study, as a correlation much lower than .90 may be considered to have a practical meaning or significance. This limitation is discussed further in the final section of the paper. Still, the low (and even negative) levels of correlation between expenditures and OPTEMPO reported in Appendix F are surprising. This is especially true of Fuel Costs, which are budgeted, as previously explained, as a function of predicted OPTEMPO. Overall, the only ship class to demonstrate any significant correlation between expenditures and OPTEMPO was the DDG – specifically SF, SO, and SR cost codes.

Based on the number of ship class / cost code combinations (45 combinations), it is not statistically infeasible that three of the combinations were spuriously significant. Therefore, a closer examination DDG OPTEMPO was

made. Since the correlations were significant, it is implied that the variation in OPTEMPO explains some of the variation in expenditures. Figure 18 is a graph of the DDG OPTEMPO categories expressed as a percent of total fuel burning days.

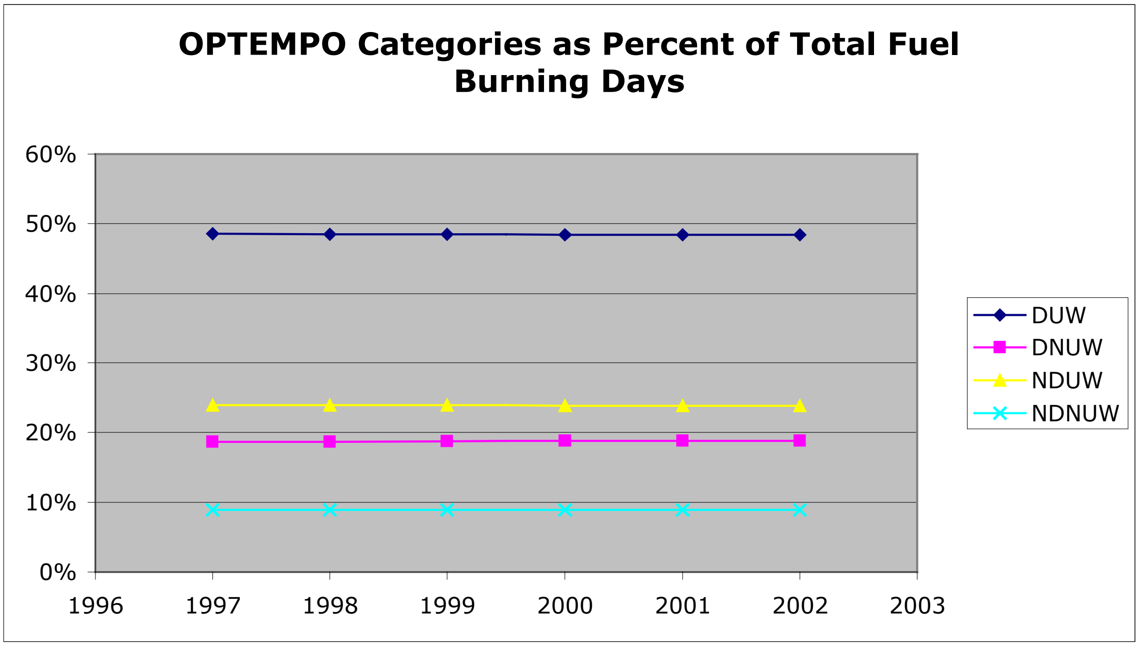

Figure 18. OPTEMPO Categories as Percent of Total Fuel Burning Days

There is very little change in the relative ratios of OPTEMPO categories from year to year, and implies that the upward trend in the DDG OPTEMPO data shown in Figure 17 may be the product of a growing ship class rather than an increase in operations. Figure 19 shows the same data as Figure 17 except with DUW expressed as a percent of total fuel burning days. Since there is very little variation in the DDG OPTEMPO data and substantially more variation in the expenditure data (see Figures 12 through 15), there must be some other factor not accounted for in this study that explains the variation in the expenditure data. Therefore, the significant correlations between OPTEMPO and expenditures are deemed too suspect to develop an accurate regression model.

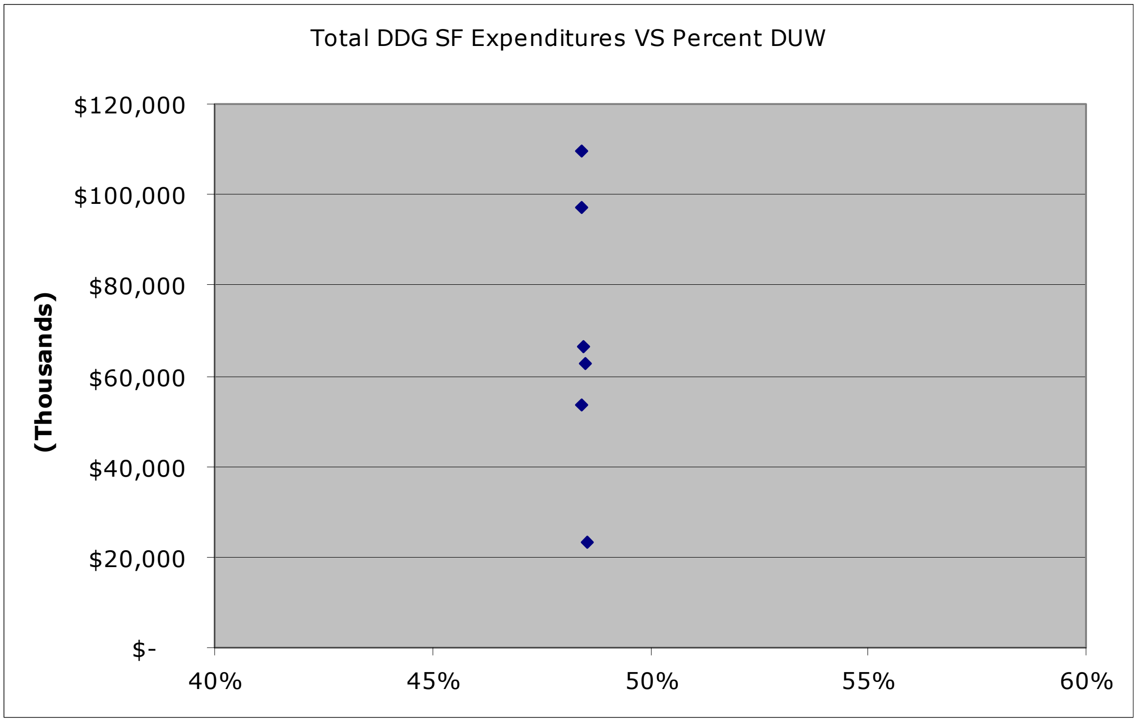

Figure 19. Total DDG SF Expenditures VS Percent DUW

THIS PAGE INTENTIONALLY LEFT BLANK

VI. CONCLUSION AND RECOMMENDATIONS

This final chapter draws conclusions from the analysis presented in the previous chapter, and discusses how this study relates to previous studies. Following the conclusions, recommendations for future studies will be suggested.

A. CONCLUSION

The relationship between OPTEMPO and expenditures remains unclear. Analysis of the data shows, with the possible exception of DDG SF, SR, and SO, there is no significant relationship between OPTEMPO and expenditures. That is not to say a relationship cannot be found. Indeed, relationships and trends were noticed in some of the data. However, these relationships were not consistent nor were they statistically significant.

The analysis reported in this study supports and helps to explain the lack of ability to improve the ship operations model by Hascall et al. As mentioned in Chapter III, nominal dollars were used in their regressions, which likely caused the variable fiscal year to become a significant independent variable. With the results of this study showing no significant relationship between OPTEMPO and expenditures, it explains the tepid OPTEMPO results previously derived when searching for cost drivers in ship expenditures in this study and the Hascall et al. study. Where the previous studies introduced in Chapter II have shown significant relationships at the TYCOM level, that significance is lost as the data is aggregated and reported to FMB for Navy level analysis. Four reasons for this lack of a definable relationship are offered in subsequent paragraphs.

The first possibility is that OPTEMPO really has no significant effect on expenditures. It may be the case that OPTEMPO as an independent factor does not have a significant effect, but it may serve to strengthen the effect of some other independent variable like inflation. Inflation was not accounted for in this study, but it has been shown to have a significant effect on operational

expenditures (Hascall et al., 2003). Inflation may explain a significant portion of expenditure variation and should be accounted for in future study.

However, in the only data set with significant correlations, it was shown that DDG OPTEMPO rates remained almost constant in the data set analyzed, and therefore, unlikely there was any explanation of the variation of expenditures inherent in DDG OPTEMPO. While the conceptualization for this study and the current vision is significant and varying OPTEMPO, it wasn't yet reflected in these data. Therefore, there either wasn't enough data or the right kind of data to establish that relationship in this study. In a few years after the Navy's new strategic mission further develops, data may better reflect the current vision of variable OPTEMPO.

The second possibility is that the lack of significant relationships is simply an artifact of the sample size. As mentioned before, a correlation does not typically need to be as high as 0.90 before it can be considered indicative of a relationship in which one variable usefully explains variance in another. However, as many of the correlations were quite small (lower than 0.2) and some were even negative, this possibility probably does not provide a complete explanation for the lack of significant relationships between OPTEMPO and costs.

The third possibility is an interrelationship between forecasting methods in deriving budget and expenditure data. The problem arises when mathematical tools attempt to analyze the patterns in the process and the effect of judgmental decisions is not well known or when a mathematical model is built to justify a judgmental process. In the case of Navy Operations and Maintenance money, judgmental decisions are made at several levels – OPNAV, TYCOM and unit. Even Congress can have a significant impact because even if the Navy made a perfect analytical estimate of operational costs, appropriations from Congress may be different due to political and judgmental decisions. The aggregate effect of these processes can cause enough unexplainable variation in the data to diminish the ability to apply analytical methods of analysis.

In addition to the third possibility lies a fourth that has been hinted at in previous chapters, and counters an assumption made in the methodology of this analysis. In Chapter II, it was discussed that TYCOMs allocate the budgeted money to units, and in the case of the 1B1B funds, there are six different TYCOMs involved in allocating resources. As in many government and civilian organizations, every dollar that is allocated is spent regardless of what those expenditures were. That is, expenditures do not necessary reflect the cost of operations but rather reflect the allocation process (Williams, 1997). Therefore, it is faulty to attempt an analysis of unit level expenditures and the effect of OPTEMPO on those expenditures at any level above the TYCOM. This further imparts credence to this and the Hascall et al. studies since it is shown that, by and large, the best method for FMB to predict cost is to use an average adjusted for inflation, because the expenditure figures used by FMB end up being based on the TYCOMs' allocation processes which can vary by TYCOM. (Hascall et al., 2003) The most practical way to derive how much it costs to operate a ship for a day is through an analysis at the TYCOM level.

One conclusion drawn from the analysis conducted in this study is the lack of significant difference in spending patterns between units within a class of ship. Through the ANOVA tests described in Chapter V, it was shown that the spending patterns amongst the same type of ship are similar in all cost code categories. This allows for the interchangeability between hull of the same class – a DDG is a DDG regardless of hull number, homeport or fleet assignment. So, when budgeting for incremental ships, the only significant factor to consider is ship class. This applies for all ships that are not in the first or last years of their commissioning as those data points were dropped from the analysis. This conclusion must contain the caveat that the lack of significance between ships of the same class may be an artifact of how TYCOMs allocate resources. If a TYCOM distributes resources as ship class packages without regard to differences in ships within each class (i.e. all DDGs are given a similar package of dollars), the conclusion reached in this study is expected since every DDG will expend every dollar allocated regardless of actual costs.

This study was unable to uncover any specific incremental costs or equations for predicting related annual costs despite an apparent correlation within the DDG class. A major point of concern was the number of commissionings in the DDG class during the period of study. The ramping-up of expenditures during the first few years of active service may have caused an artificially high correlation between DDG OPTEMPO and expenditures since both expenditures and OPTEMPO increased as new ships joined the class. This highlights a weakness of aggregated data. If OPTEMPO data were obtained at the unit level, a more thorough analysis of the variation in OPTEMPO could be done.

B. RECOMMENDATIONS FOR FUTURE STUDY

The following are recommendations based on findings in this and other studies that may provide a better understanding of how OPTEMPO affects expenditures within the surface fleet.

1. OPTEMPO in Context

OPTEMPO was studied as a solitary factor in the expenditure analysis. OPMONTH was also initially considered for analysis, but it was determined that employment data would provide a much better and more granular picture of OPTEMPO. However, it may make sense, in a future study, to combine OPMONTH and employment data or ship years and employment data to see if these combinations create a significant correlation with expenditure data. As these factors are likely to be intercorrelated and appropriate analysis must be conducted to account for that possibility. Monthly data would also provide a much larger sample size, and allow the meaningful interpretation of relationships with much smaller correlation coefficients. This data set may not be available for a few years following this study, as the next few years should provide essential data representing the current vision of variable OPTEMPO.

All the data used in this study came through the office of the study's sponsor, FMB-1. However, there is another potentially viable source of data that

may be used in subsequent studies. The Navy Cost Analysis Division (NCAD) of FMB, with the support of IBM Business Consulting Services, maintains an electronic database of ship specific operational data entitled Navy Visibility and Management of Operating and Support Costs (VAMSOC) that can be queried, downloaded and analyzed by DoD personnel (NCAD, 2003). No analysis or validation was done on this data set. However, at a cursory glance, this data appears to be a viable source for future study.

2. Submarines

Submarines were not studied due to the lack of ability to obtain employment data. The submarine force has a significant impact on the Navy O&M budget due to the sizable fleet. Future studies not inhibited by security classification could analyze operational and expenditure data. Particular attention should be paid to SO and SR costs. Obviously, this should not be done until the underlying issue with capturing true data is resolved.

3. Level of Service

The goal of this study was to uncover the relationship between cost and OPTEMPO, but a complete picture of the impact of OPTEMPO would also need to address its impact on level of service. This study lacked the ability to analyze risk in the form of level of service to the fleet. An initial step in such an analysis would be the development of a robust level of service construct in terms of observable variables. Once such a construct is operationalized, research could be done to find a valid model of this variable and its relationship to costs and OPTEMPO. These relationships are likely to be dynamic, and dynamic modeling tools (e.g., simulation or systems of differential equations) must be used to establish a functional understanding of those relationships. The advantage to having this variable is to estimate adequate funding levels and the associated risks of over or under funding.

4. Process Analysis

In order for this budgeting process to move away from a judgmental forecasting base to a more mathematical forecasting process, a thorough analysis should be done of the entire process. During the course of this study, no analysis was discovered that spanned the process from OPNAV to the unit. This strategic management analysis could address specific points in which an mathematic approach to forecasting or allocating data breaks down. Strategically mapping the process makes analytical analysis more focused and relevant within the framework of the mathematical forecasting process.

5. Future OPNAV Analysis

Given the conclusions of this study, future study of expenditures and OPTEMPO at the OPNAV level would be irrelevant. Studies of general TYCOM interactions and allocations made to the TYCOMs may produce an interesting study. However, stipulating the data supplied for this study was a true representation of the data available at the FMB level, any future attempts at analysis beyond allocations to the TYCOMs will be futile without a clear understanding of the intra-TYCOM allocation processes. Future analysis should focus on TYCOM allocations and attempting to derive operational costs at that level.

APPENDIX A: INITIAL ANOVA

The following are the outputs from the initial ANOVA done on expenditures by UIC. Each analysis is broken down by ship class and cost code. The treatments in each analysis are the individual units.

CV/CT

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.9095E+10	12	4924544264	0.59981533	0.83447983	1.90436822
Within Groups	5.3366E+11	65	8210100704			
Total	5.9275E+11	77				

CV/SF

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.2931E+15	12	2.7442E+14	12.483509	1.1084E-12	1.90436822
Within Groups	1.4289E+15	65	2.1983E+13			
Total	4.7219E+15	77				

CV/SO

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.8575E+14	12	3.2146E+13	3.81984657	0.0002077	1.90436822
Within Groups	5.4701E+14	65	8.4155E+12			
Total	9.3276E+14	77				

CV/SR

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.3475E+14	12	1.9563E+13	2.24751729	0.01900557	1.90436822
Within Groups	5.6576E+14	65	8.7041E+12			
Total	8.0052E+14	77				

CV/SU

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.2797E+13	12	3.5664E+12	3.50384661	0.00050834	1.90436822
Within Groups	6.6161E+13	65	1.0179E+12			
Total	1.0896E+14	77				

Figure 20. Initial CV ANOVA

CG/CT

urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	1.7979E+10	22	817216280	0.88106858	0.61892636	1.63561253
Within Groups	1.0667E+11	115	927528573			
Total	1.2464E+11	137				

CG/SF

urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	3.0593E+13	22	1.3906E+12	0.48125333	0.97491496	1.63561253
Within Groups	3.323E+14	115	2.8895E+12			
Total	3.6289E+14	137				

CG/SO

urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	2.8867E+12	22	1.3121E+11	1.23199602	0.2356393	1.63561253
Within Groups	1.2248E+13	115	1.065E+11			
Total	1.5135E+13	137				

CG/SR

urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	5.3386E+13	22	2.4266E+12	3.48817851	6.4501E-06	1.63561253
Within Groups	8.0002E+13	115	6.9567E+11			
Total	1.3339E+14	137				

CG/SU

urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	2.7077E+12	22	1.2308E+11	1.49864286	0.08790294	1.63561253
Within Groups	9.4444E+12	115	8.2125E+10			
Total	1.2152E+13	137				

Figure 21. Initial CG ANOVA

FFG/CT

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7171686757	26	275834106	0.7978701	0.74377374	1.5778614
Within Groups	4.6671E+10	135	345713048			
Total	5.3843E+10	161				

FFG/SF

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.9798E+12	26	2.2999E+11	0.89101329	0.62016261	1.5778614
Within Groups	3.4847E+13	135	2.5812E+11			
Total	4.0826E+13	161				

FFG/SO

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.0872E+12	26	1.572E+11	3.81941786	1.6699E-07	1.5778614
Within Groups	5.5564E+12	135	4.1158E+10			
Total	9.6436E+12	161				

FFG/SR

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.8193E+13	26	6.9973E+11	4.53403254	2.8986E-09	1.5778614
Within Groups	2.0834E+13	135	1.5433E+11			
Total	3.9028E+13	161				

FFG/SU

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.2117E+11	26	2.0045E+10	1.69072243	0.02892121	1.5778614
Within Groups	1.6005E+12	135	1.1856E+10			
Total	2.1217E+12	161				

Figure 22. Initial FFG ANOVA

DD/CT						
urce of Variatic	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grou	5877546827	20	293877341	0.8046168	0.70290533	1.67135639
Within Groups	3.835E+10	105	365238883			
Total	4.4228E+10	125				

DD/SF						
urce of Variatic	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grou	1.4084E+13	20	7.0421E+11	0.46144404	0.97506897	1.67135639
Within Groups	1.6024E+14	105	1.5261E+12			
Total	1.7432E+14	125				

DD/SO						
urce of Variatic	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grou	2.4364E+12	20	1.2182E+11	2.28508059	0.00367842	1.67135639
Within Groups	5.5976E+12	105	5.331E+10			
Total	8.034E+12	125				

DD/SR						
urce of Variatic	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grou	1.0618E+13	20	5.3089E+11	1.81189601	0.02829617	1.67135639
Within Groups	3.0765E+13	105	2.93E+11			
Total	4.1383E+13	125				

DD/SU						
urce of Variatic	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grou	6.8659E+11	20	3.4329E+10	1.31882444	0.18375059	1.67135639
Within Groups	2.7332E+12	105	2.603E+10			
Total	3.4198E+12	125				

Figure 23. Initial DD ANOVA

LHA/CT						
urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	75696671.2	4	18924167.8	0.838104	0.51401707	2.75871059
Within Groups	564493421	25	22579736.8			
Total	640190092	29				

LHA/SF						
urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	6.9361E+12	4	1.734E+12	0.41993902	0.79268625	2.75871059
Within Groups	1.0323E+14	25	4.1292E+12			
Total	1.1017E+14	29				

LHA/SO						
urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	3.9457E+12	4	9.8644E+11	2.24164444	0.09322854	2.75871059
Within Groups	1.1001E+13	25	4.4005E+11			
Total	1.4947E+13	29				

LHA/SR						
urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	1.5582E+12	4	3.8955E+11	0.45721219	0.7662789	2.75871059
Within Groups	2.13E+13	25	8.5202E+11			
Total	2.2859E+13	29				

LHA/SU						
urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	6.0228E+12	4	1.5057E+12	1.38972323	0.26612637	2.75871059
Within Groups	2.7086E+13	25	1.0835E+12			
Total	3.3109E+13	29				

Figure 24. Initial LHA ANOVA

LPD/CT						
urce of Variatic	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grou	2840245655	10	284024566	0.88946029	0.54864139	2.00779127
Within Groups	1.7563E+10	55	319322368			
Total	2.0403E+10	65				

LPD/SF						
urce of Variatic	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grou	1.7688E+12	10	1.7688E+11	0.16434749	0.99799789	2.00779127
Within Groups	5.9195E+13	55	1.0763E+12			
Total	6.0964E+13	65				

LPD/SO						
urce of Variatic	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grou	1.2916E+12	10	1.2916E+11	1.66221633	0.11360954	2.00779127
Within Groups	4.2737E+12	55	7.7703E+10			
Total	5.5652E+12	65				

LPD/SR						
urce of Variatic	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grou	1.6516E+11	10	1.6516E+10	0.27540396	0.98413758	2.00779127
Within Groups	3.2983E+12	55	5.997E+10			
Total	3.4635E+12	65				

LPD/SU						
urce of Variatic	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Grou	1.6189E+12	10	1.6189E+11	1.95712626	0.05651166	2.00779127
Within Groups	4.5494E+12	55	8.2717E+10			
Total	6.1683E+12	65				

Figure 25. Initial LPD ANOVA

LSD/CT

urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	4.6437E+10	14	3316944480	0.95816163	0.50317751	1.82591009
Within Groups	2.5963E+11	75	3461779702			
Total	3.0607E+11	89				

LSD/SF

urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	1.7578E+13	14	1.2556E+12	2.36989736	0.00875135	1.82591009
Within Groups	3.9735E+13	75	5.298E+11			
Total	5.7313E+13	89				

LSD/SO

urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	2.0399E+12	14	1.4571E+11	1.56744139	0.10875086	1.82591009
Within Groups	6.972E+12	75	9.296E+10			
Total	9.012E+12	89				

LSD/SR

urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	2.4284E+12	14	1.7345E+11	2.42257954	0.00736098	1.82591009
Within Groups	5.3699E+12	75	7.1599E+10			
Total	7.7983E+12	89				

LSD/SU

urce of Variatic	SS	df	MS	F	P-value	F crit
Between Grou	8.5373E+11	14	6.0981E+10	0.92490641	0.53662097	1.82591009
Within Groups	4.9449E+12	75	6.5932E+10			
Total	5.7986E+12	89				

Figure 26. Initial LSD ANOVA

LHD/CT						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2525856796	6	420976133	0.81671865	0.56439483	2.37178455
Within Groups	1.8041E+10	35	515448170			
Total	2.0567E+10	41				

LHD/SF						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.0203E+14	6	1.7004E+13	2.28672678	0.05749493	2.37178455
Within Groups	2.6026E+14	35	7.436E+12			
Total	3.6229E+14	41				

LHD/SO						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.6676E+13	6	2.7793E+12	5.72229858	0.0003148	2.37178455
Within Groups	1.6999E+13	35	4.8569E+11			
Total	3.3675E+13	41				

LHD/SR						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.8135E+13	6	3.0225E+12	4.36971397	0.00215116	2.37178455
Within Groups	2.4209E+13	35	6.9169E+11			
Total	4.2344E+13	41				

LHD/SU						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.3333E+12	6	7.2221E+11	2.31784454	0.05462993	2.37178455
Within Groups	1.0906E+13	35	3.1159E+11			
Total	1.5239E+13	41				

Figure 27. Initial LHD ANOVA

AOE/CT

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5414979089	6	902496515	0.64840555	0.6909975	2.37178455
Within Groups	4.8715E+10	35	1391870435			
Total	5.413E+10	41				

AOE/SF

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.3556E+13	6	3.926E+12	0.55937364	0.75941776	2.37178455
Within Groups	2.4565E+14	35	7.0185E+12			
Total	2.692E+14	41				

AOE/SO

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.6196E+12	6	2.6993E+11	1.66077112	0.15999595	2.37178455
Within Groups	5.6886E+12	35	1.6253E+11			
Total	7.3082E+12	41				

AOE/SR

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.3638E+12	6	7.2729E+11	4.51258702	0.0017414	2.37178455
Within Groups	5.641E+12	35	1.6117E+11			
Total	1.0005E+13	41				

AOE/SU

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.1001E+13	6	1.8335E+12	0.97131932	0.45889528	2.37178455
Within Groups	6.6067E+13	35	1.8876E+12			
Total	7.7067E+13	41				

Figure 28. Initial AOE ANOVA

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX B: GRAPHS OF INITIALLY SIGNIFICANT UIC DATA

This appendix contains the graphs of the expenditure data by ship class and cost code. All UICs are graphed on one chart in order to facilitate the detection of patterns and potential outliers. Only the graphs of the data that was determined to demonstrate significant differences between ships of the same class from the initial ANOVA tests.

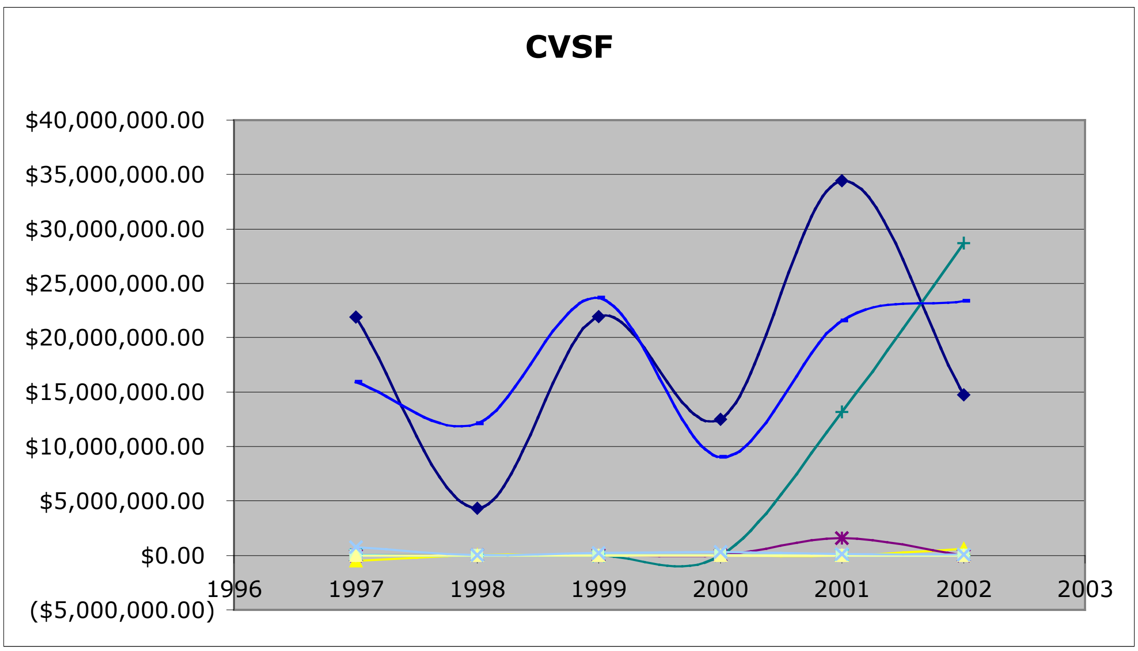

Figure 29. CV SF Expenditures by Year

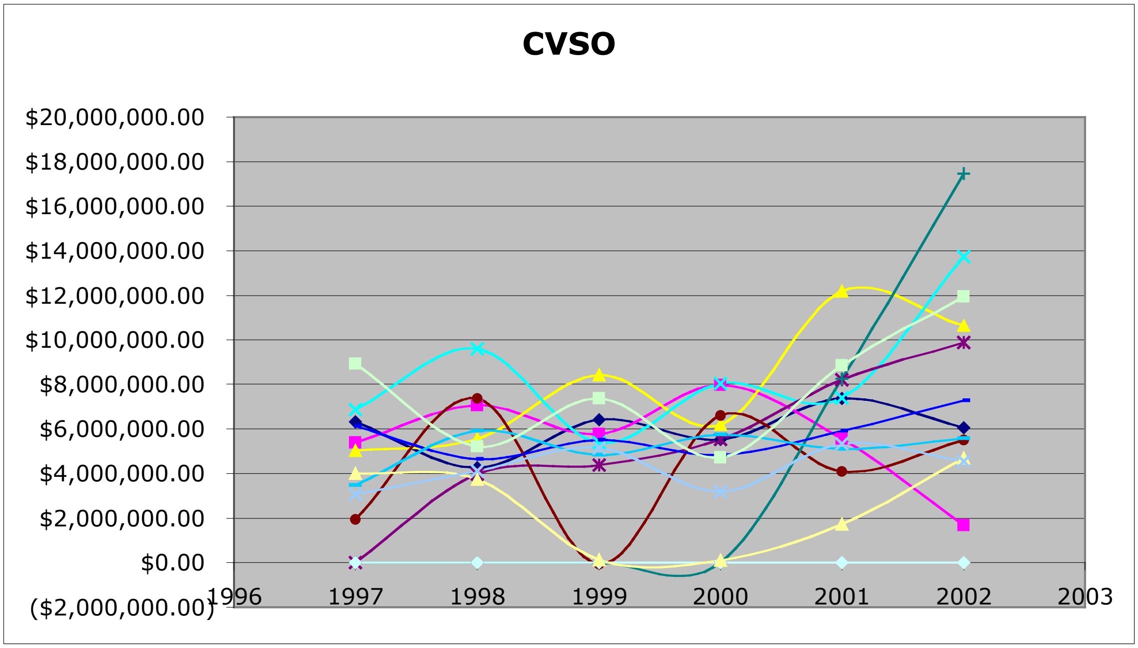

Figure 30. CV SO Expenditures by Year

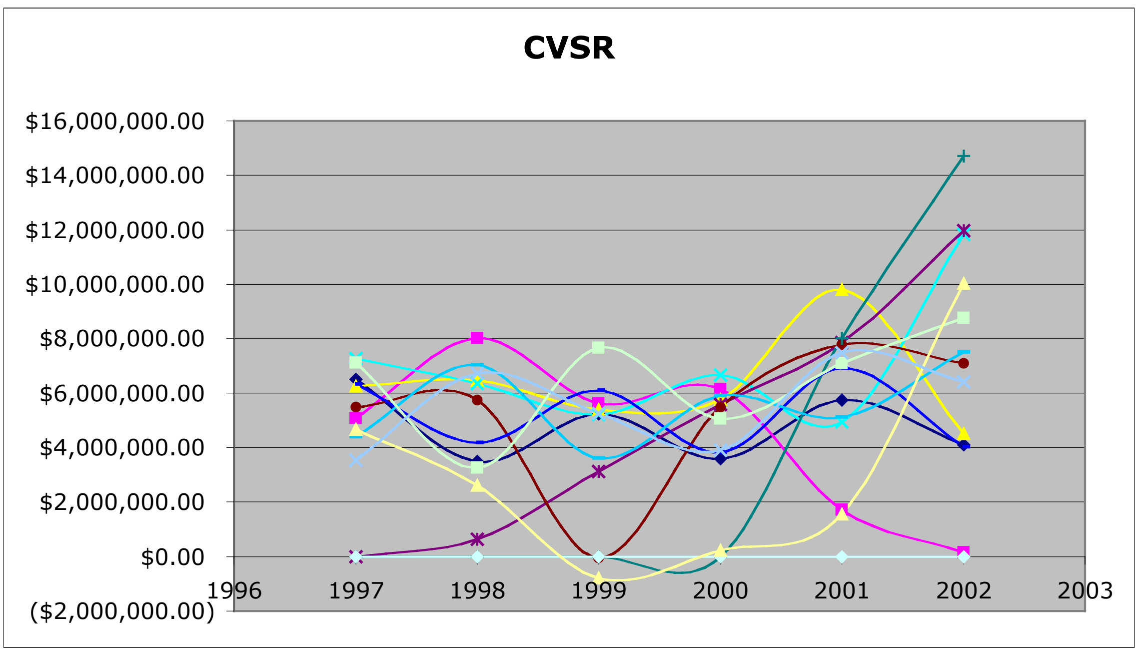

Figure 31. CV SR Expenditures by Year

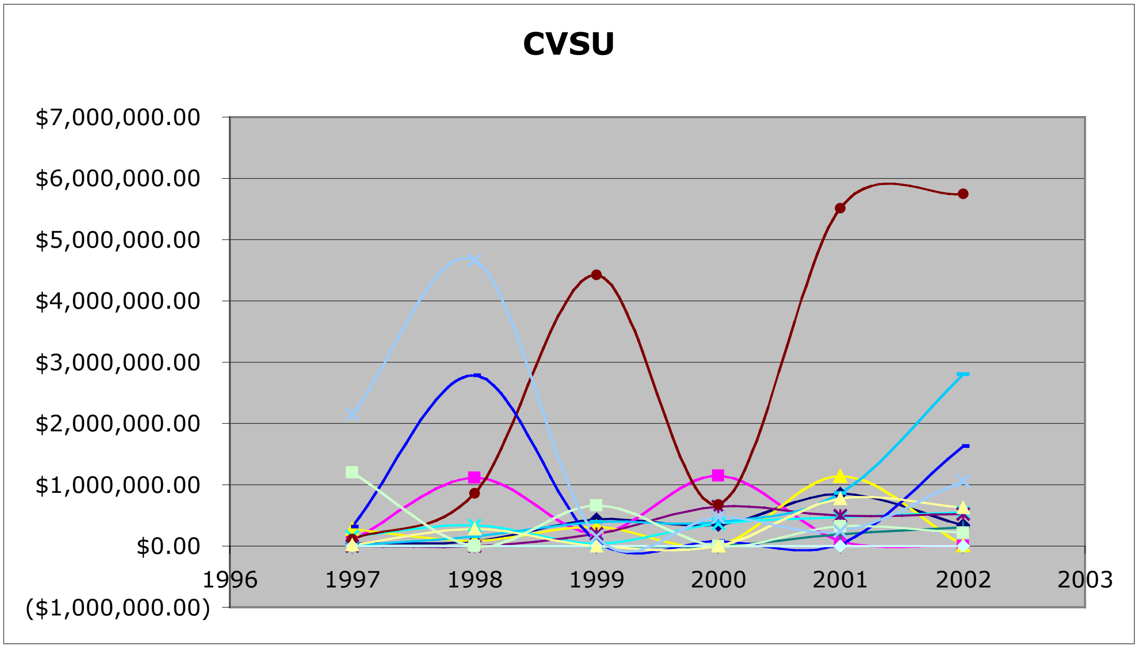

Figure 32. CV SU Expenditures by Year

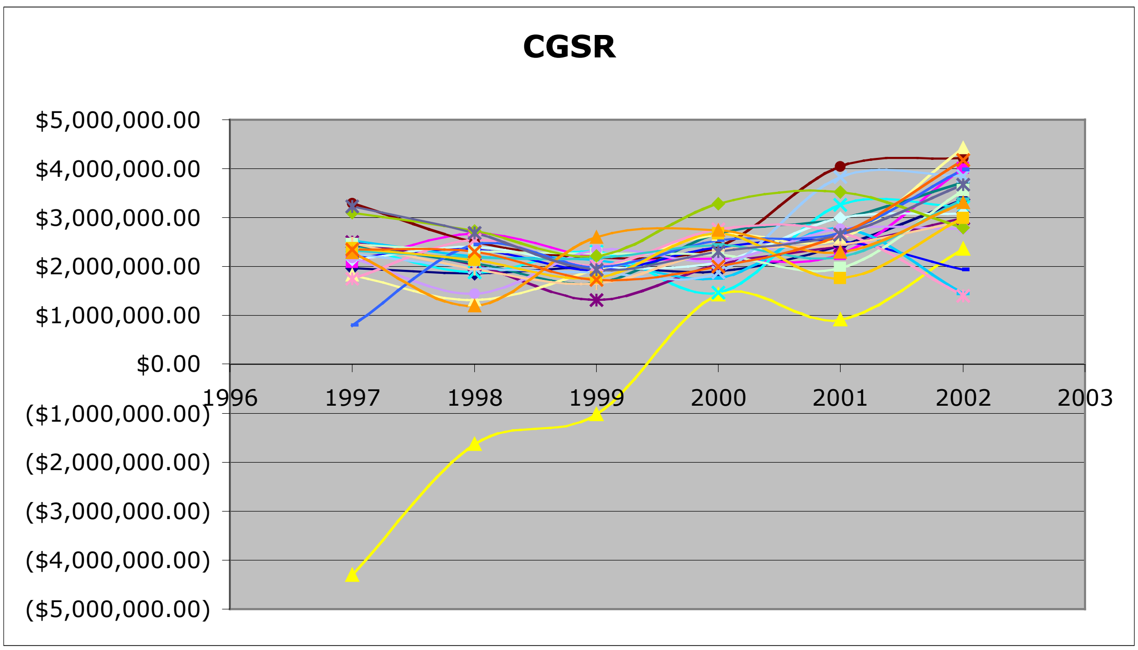

Figure 33. CG SR Expenditures by Year

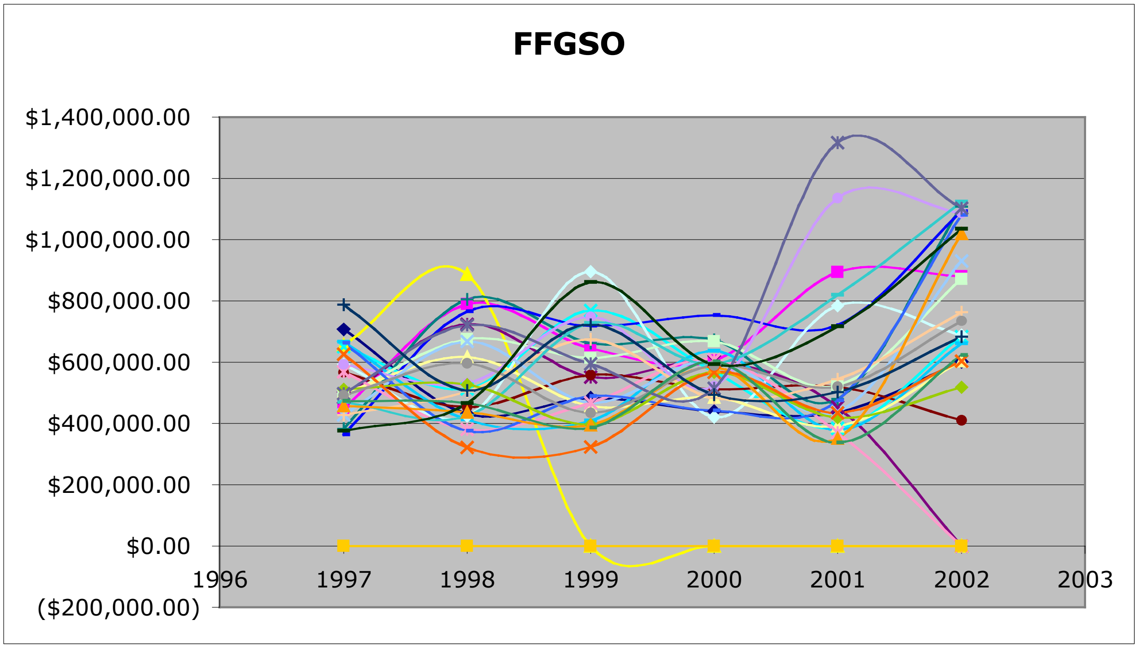

Figure 34. FFG SO Expenditures by Year

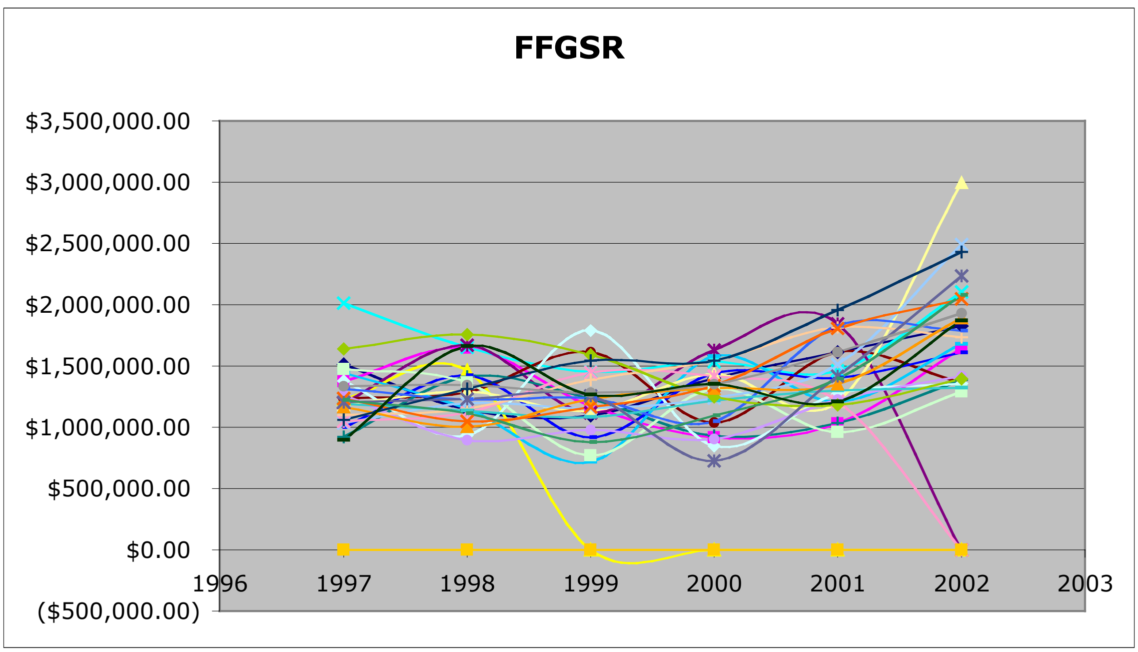

Figure 35. FFG SR Expenditures by Year

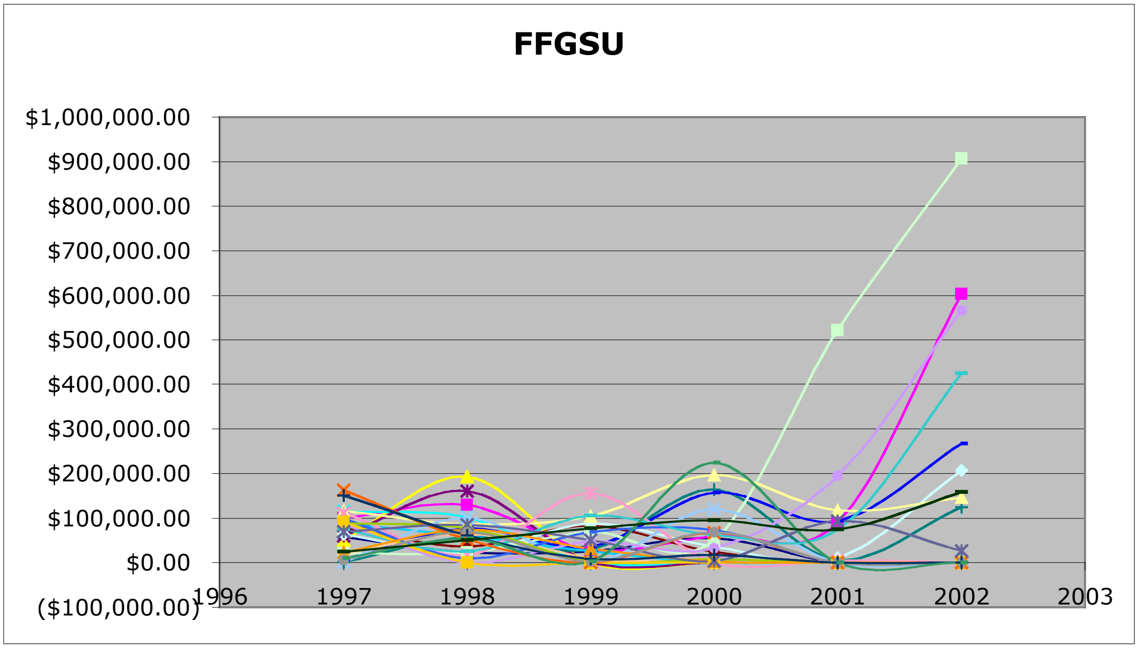

Figure 36. FFG SU Expenditures by Year

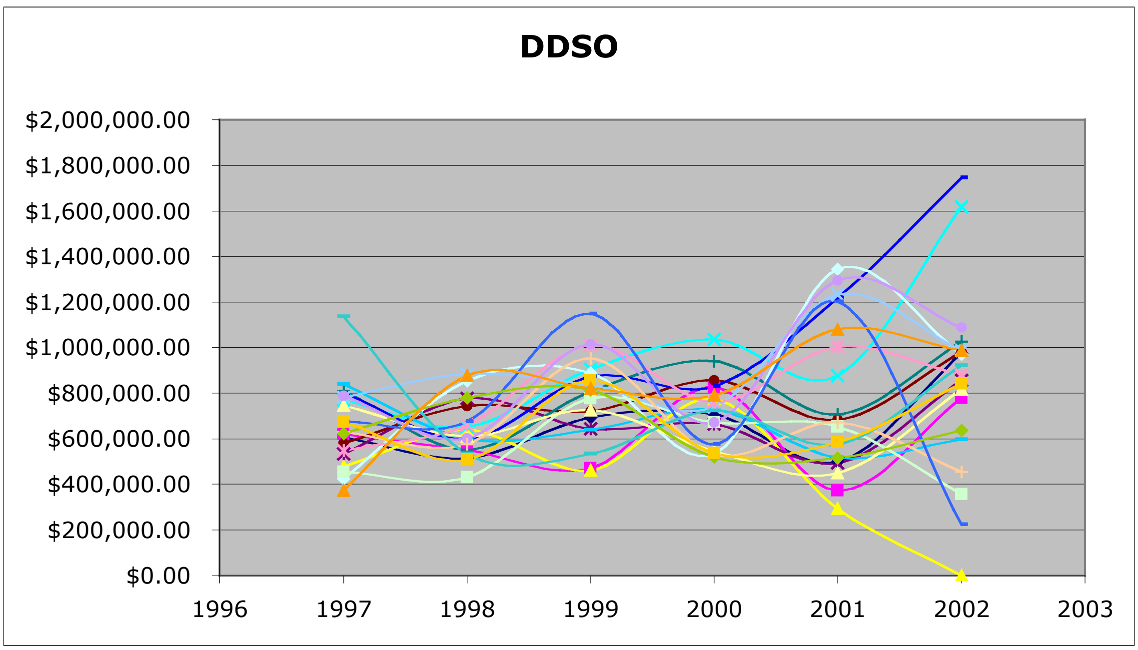

Figure 37. DD SO Expenditures by Year

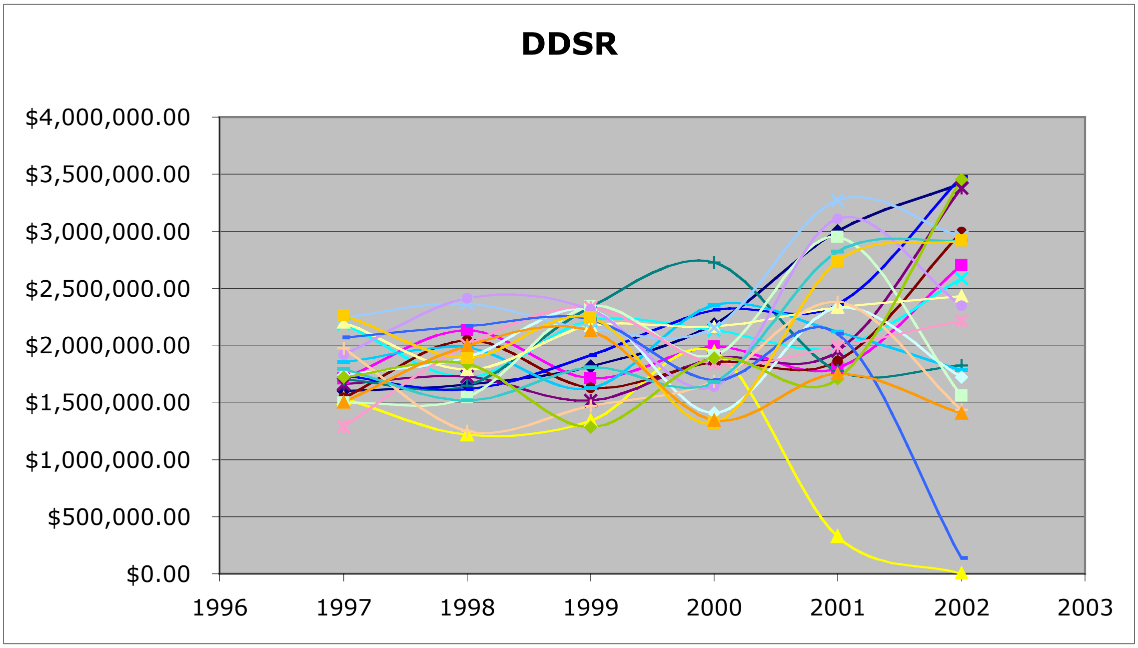

Figure 38. DD SR Expenditures by Year

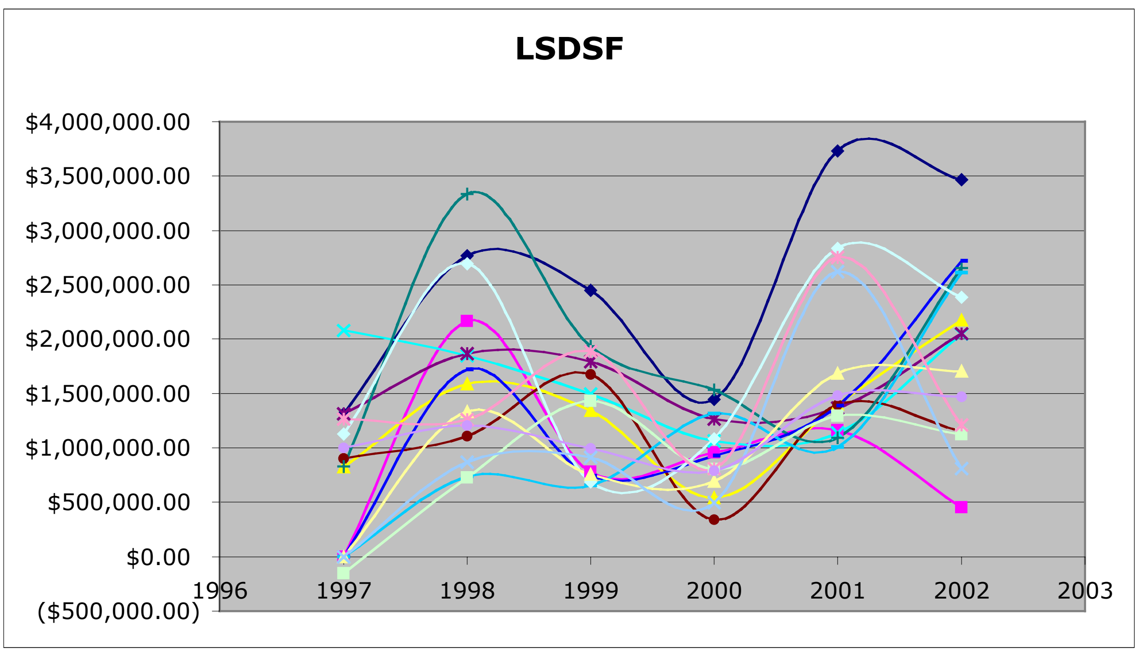

Figure 39. LSD SF Expenditures by Year

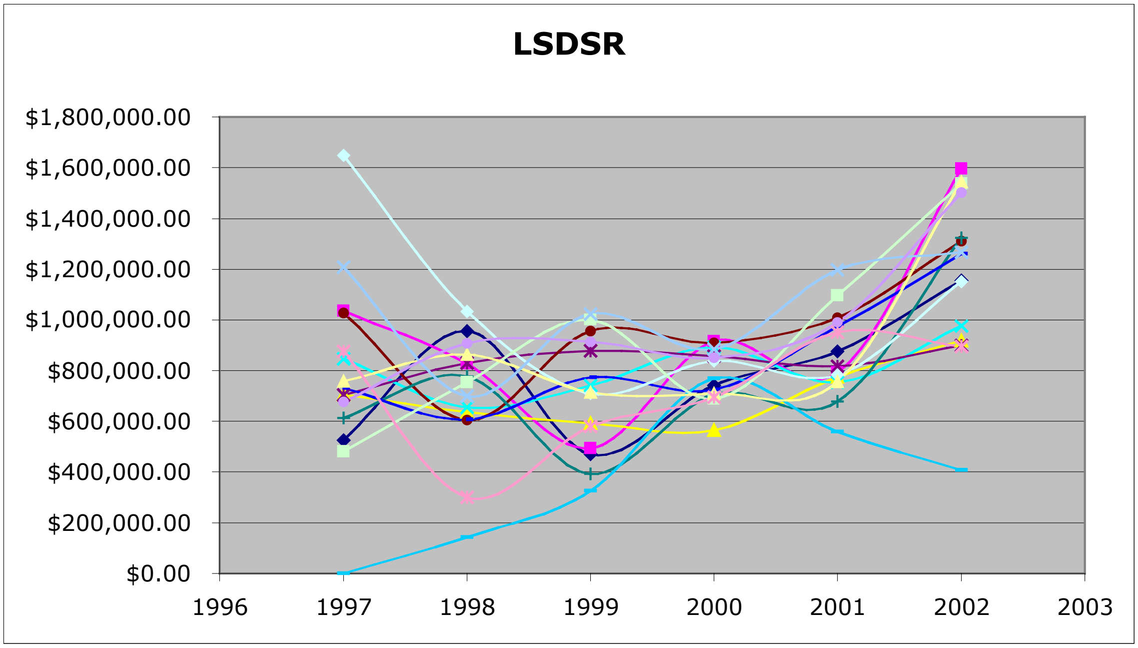

Figure 40. LSD SR Expenditures by Year

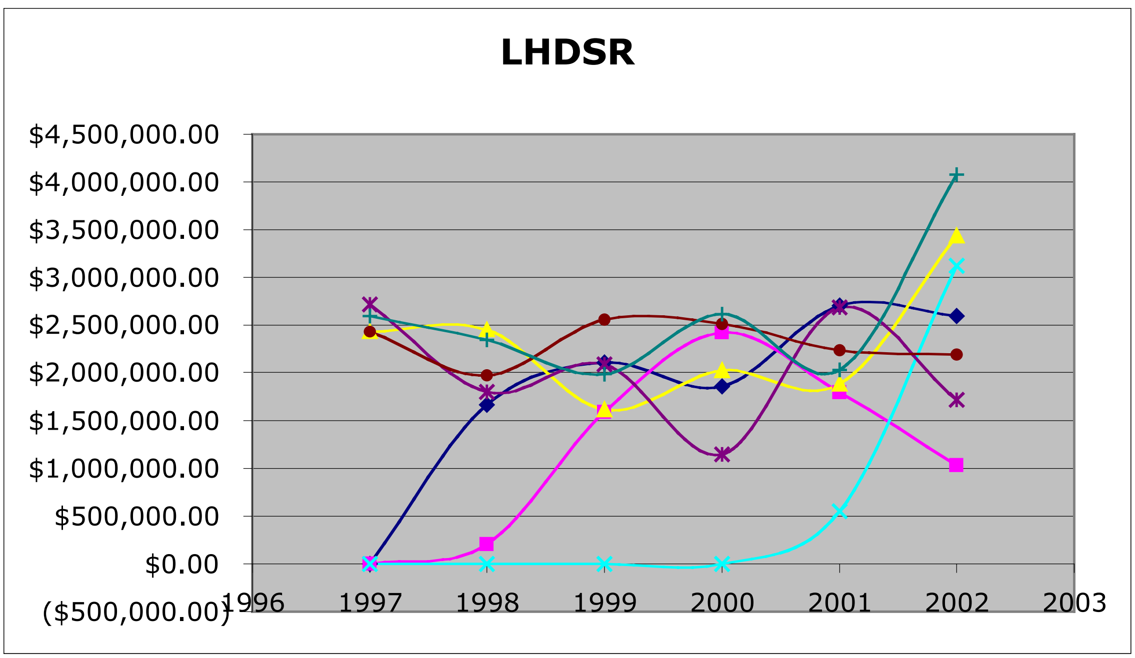

Figure 41. LHD SR Expenditures by Year

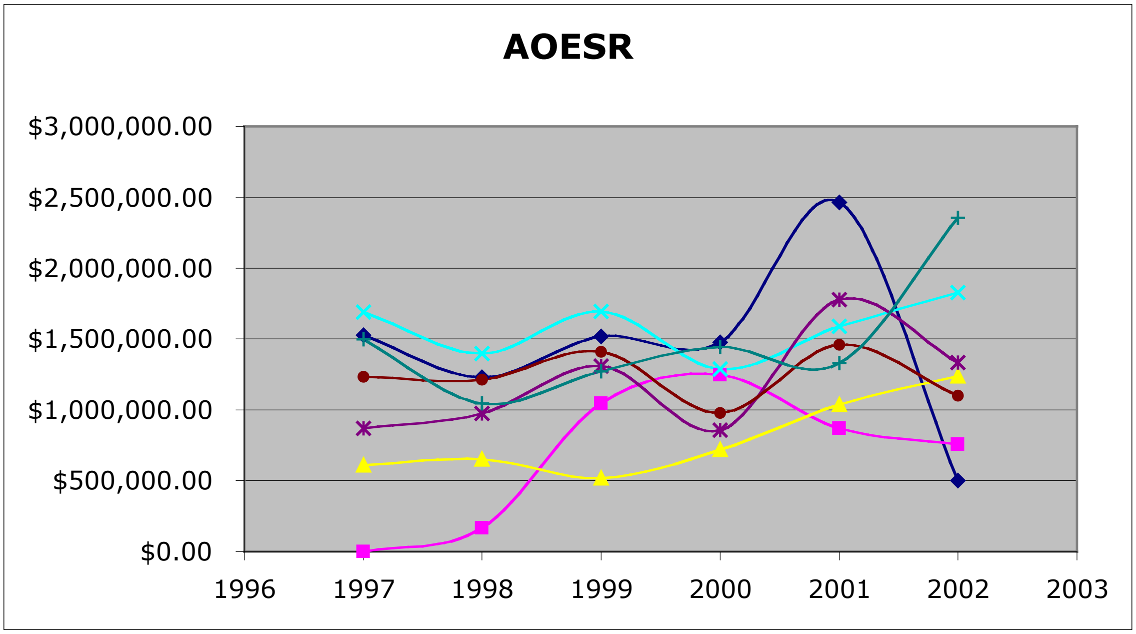

Figure 42. AOE SR Expenditures by Year

APPENDIX C: GRAPHS DATA FOLLOWING DATA GROOM

This appendix contains the graphs of the expenditure data by ship class and cost code after the data was groomed.

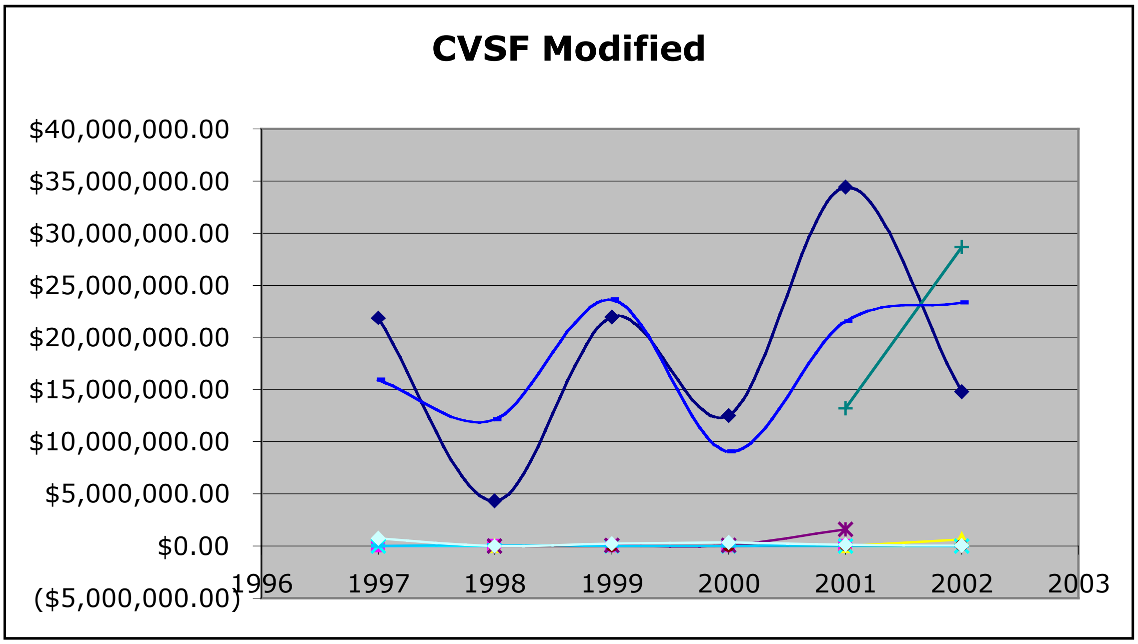

Figure 43. CV SF After Data Groom

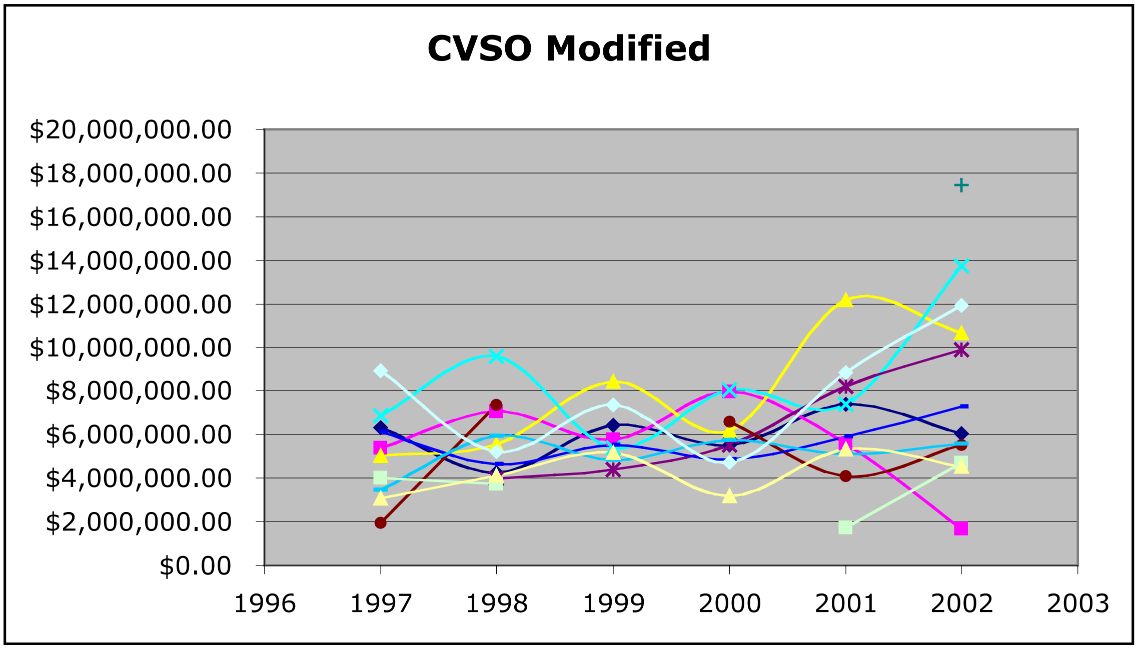

Figure 44. CV SO After Data Groom

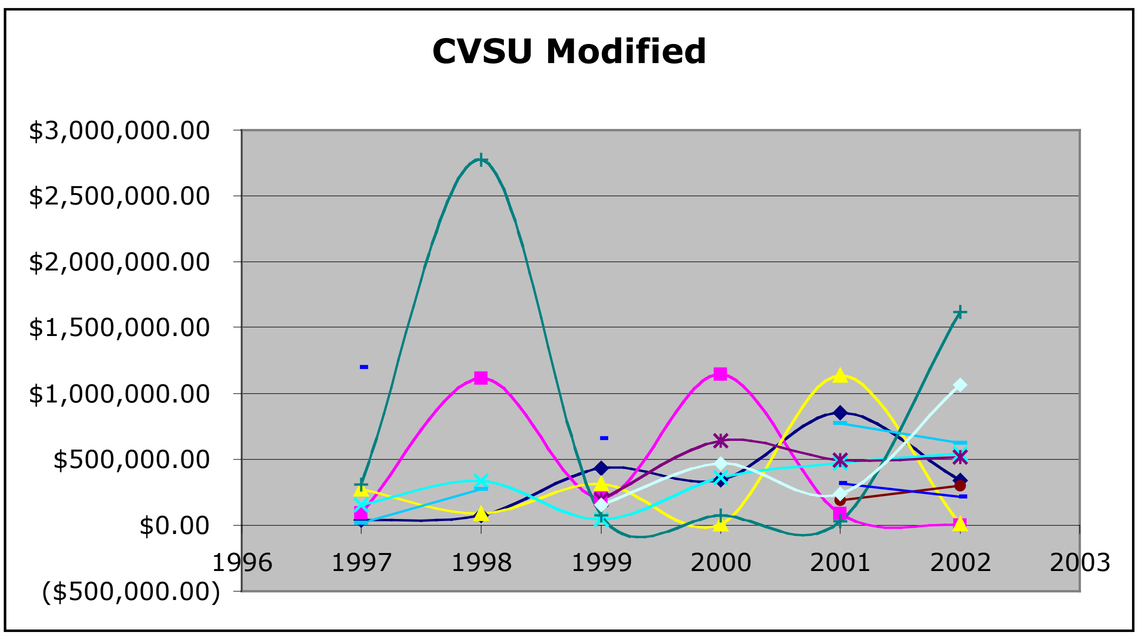

Figure 45. CV SU After Data Groom

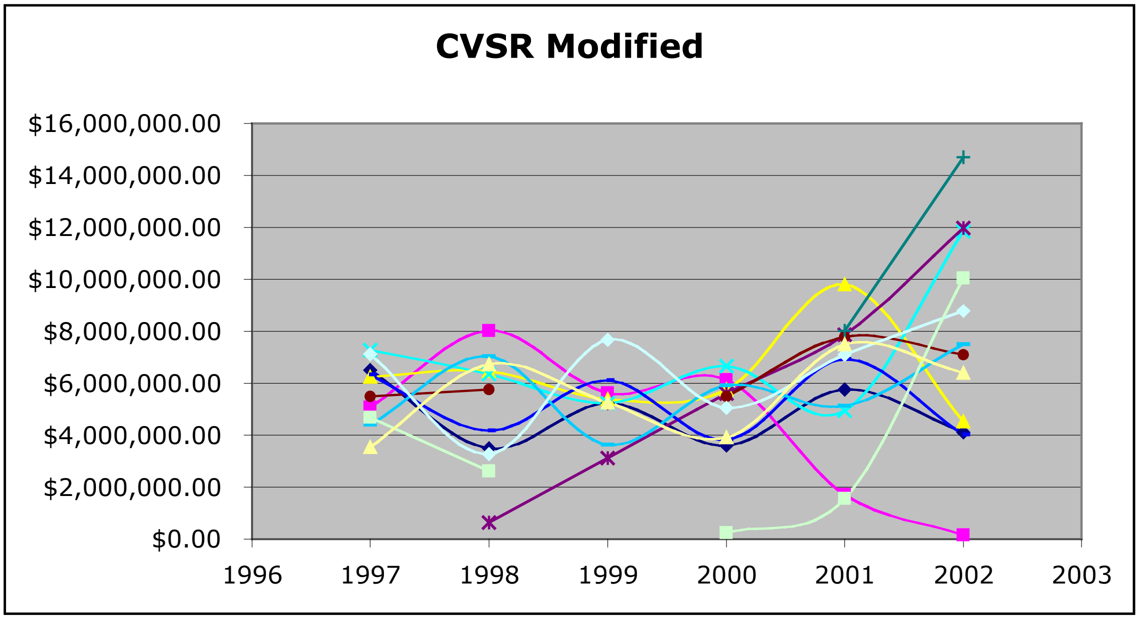

Figure 46. CV SR After Data Groom

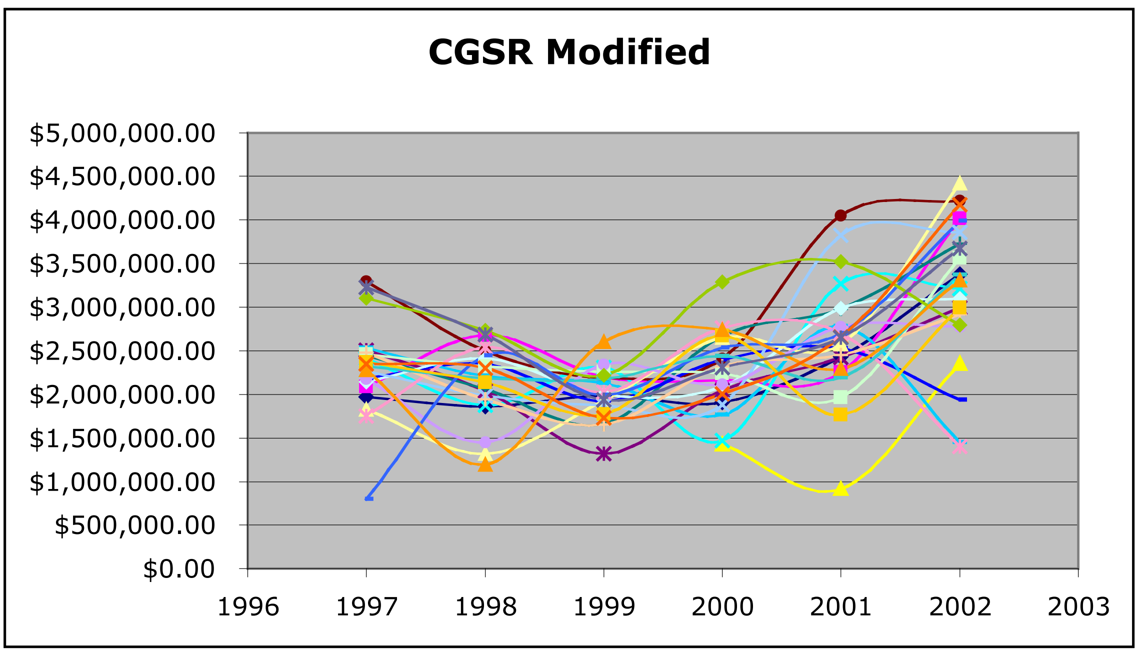

Figure 47. CG SR After Data Groom

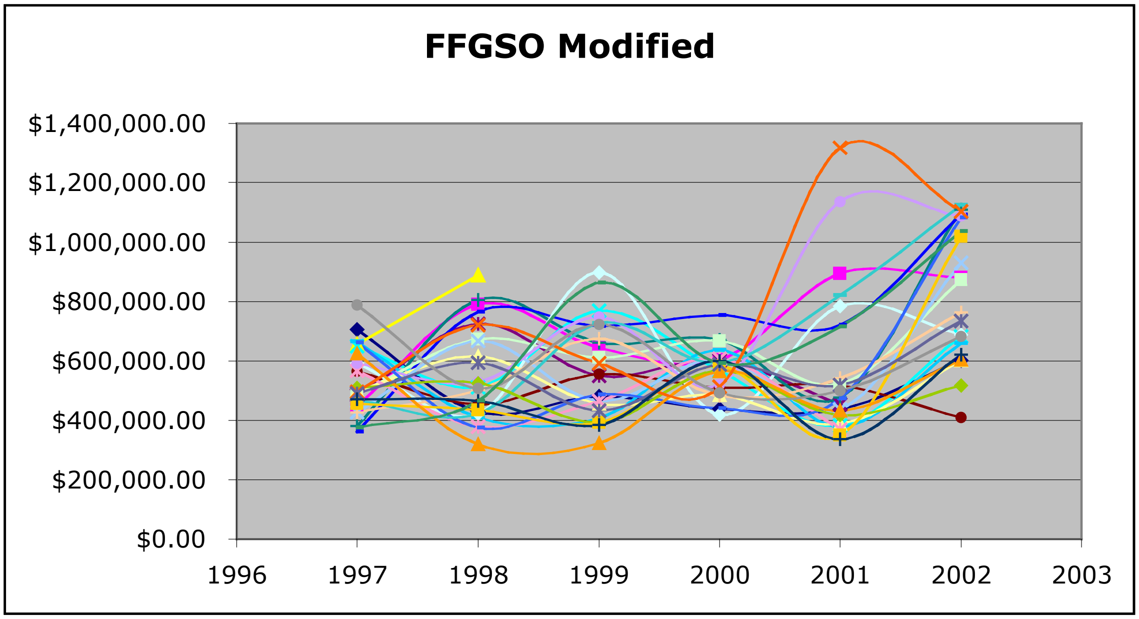

Figure 48. FFG SO After Data Groom

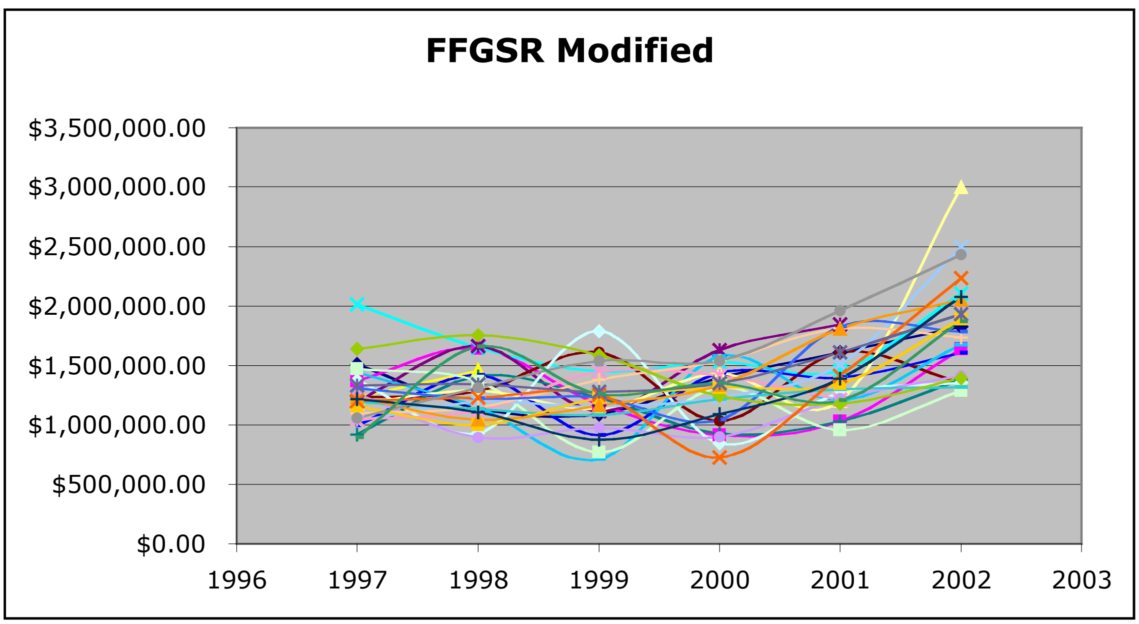

Figure 49. FFG SR After Data Groom

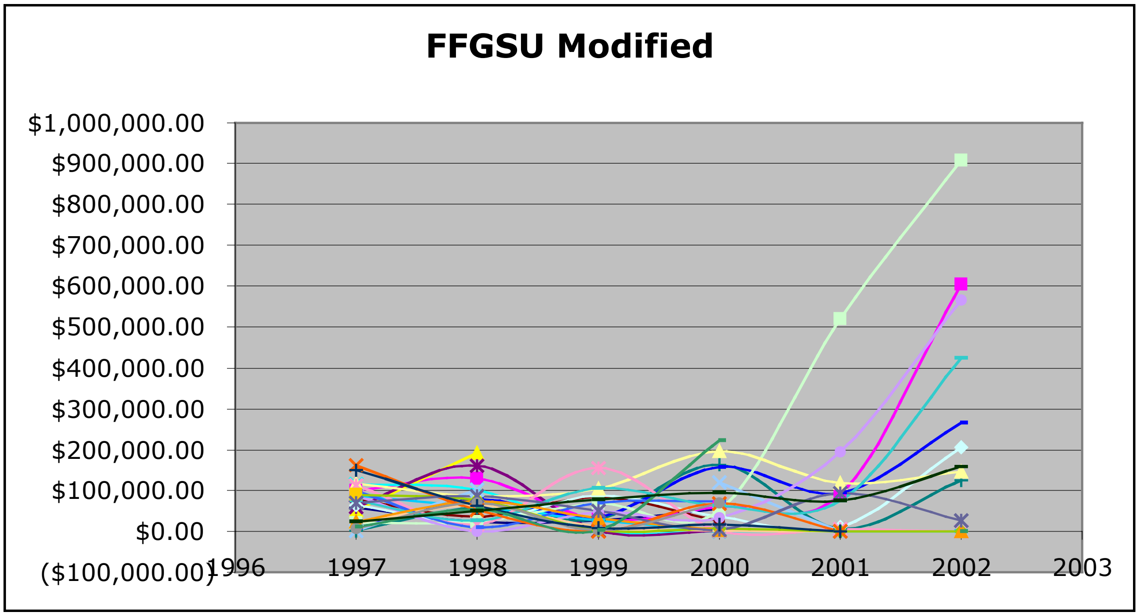

Figure 50. FFG SU After Data Groom

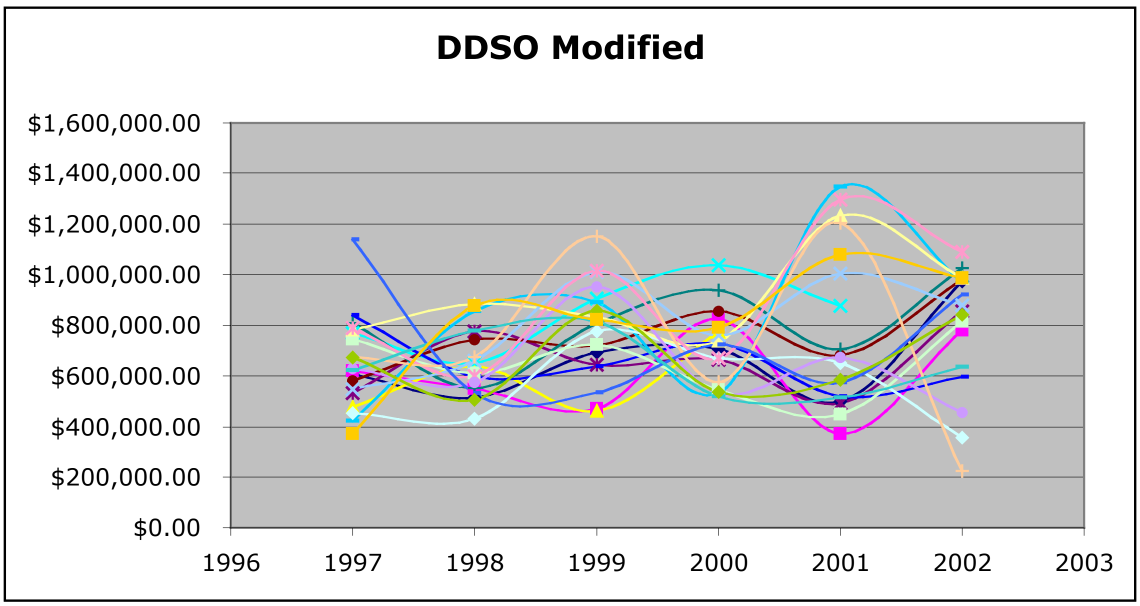

Figure 51. DD SO After Data Groom

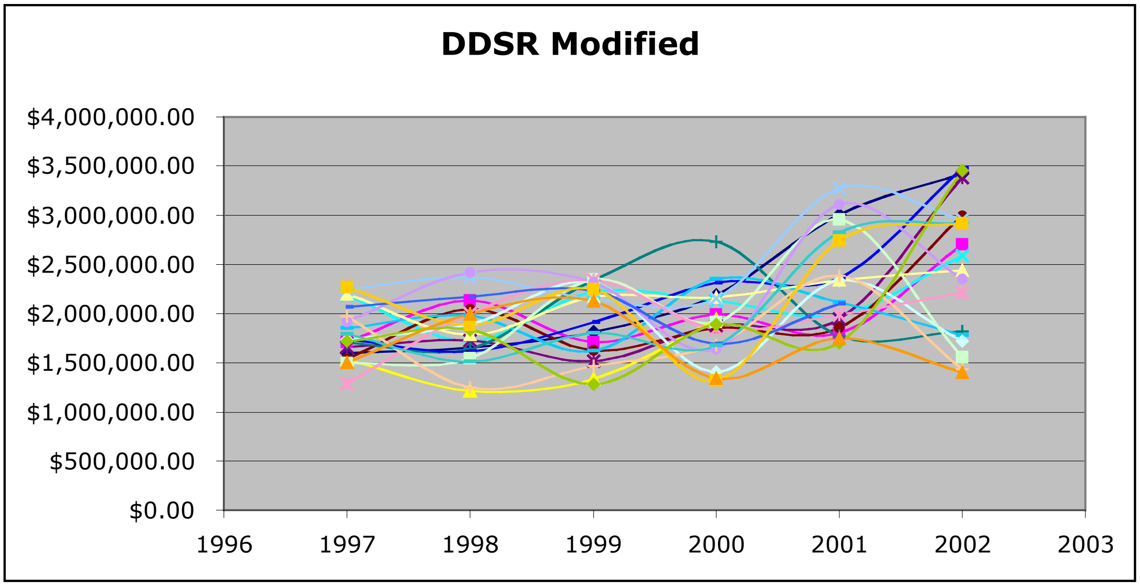

Figure 52. DD SR After Data Groom

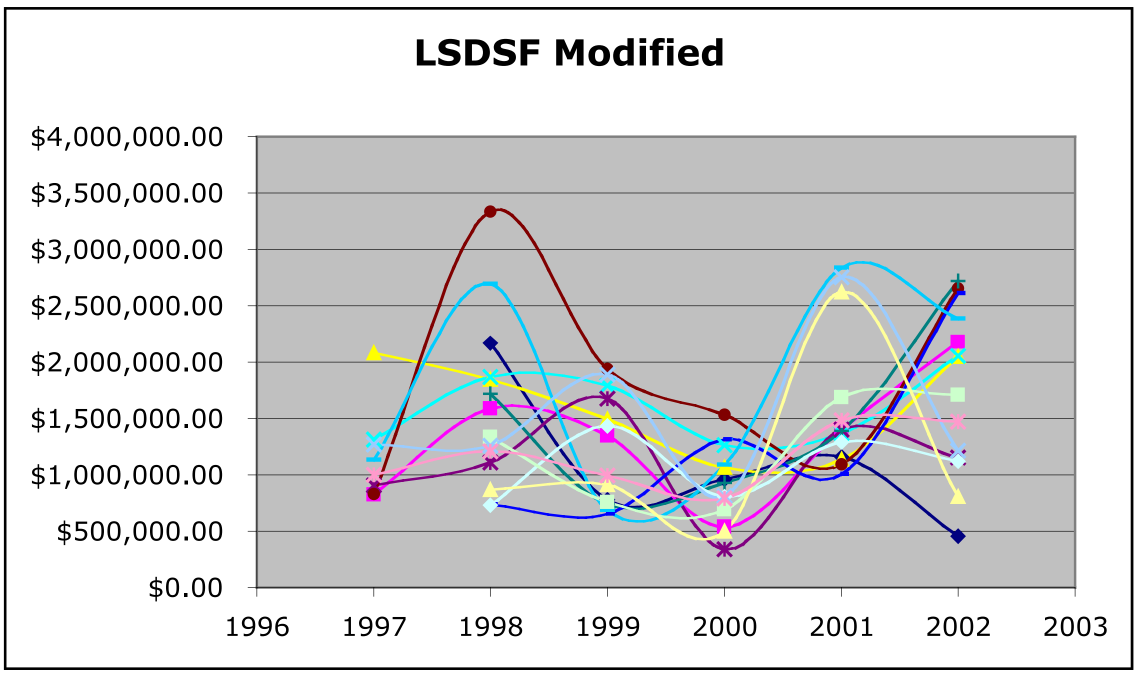

Figure 53. LSD SF After Data Groom

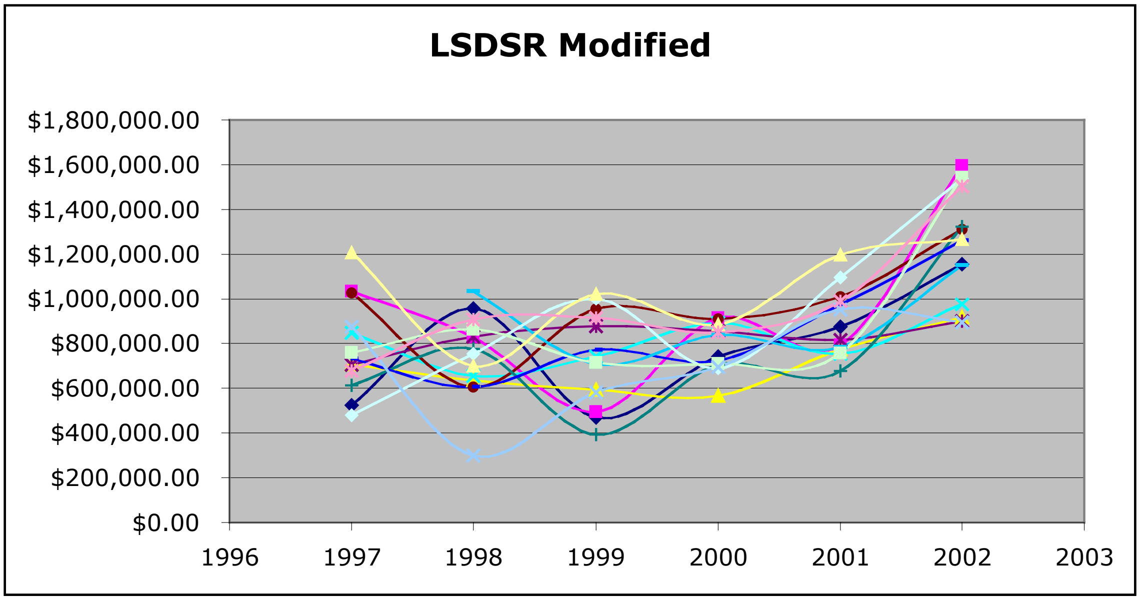

Figure 54. LSD SR After Data Groom

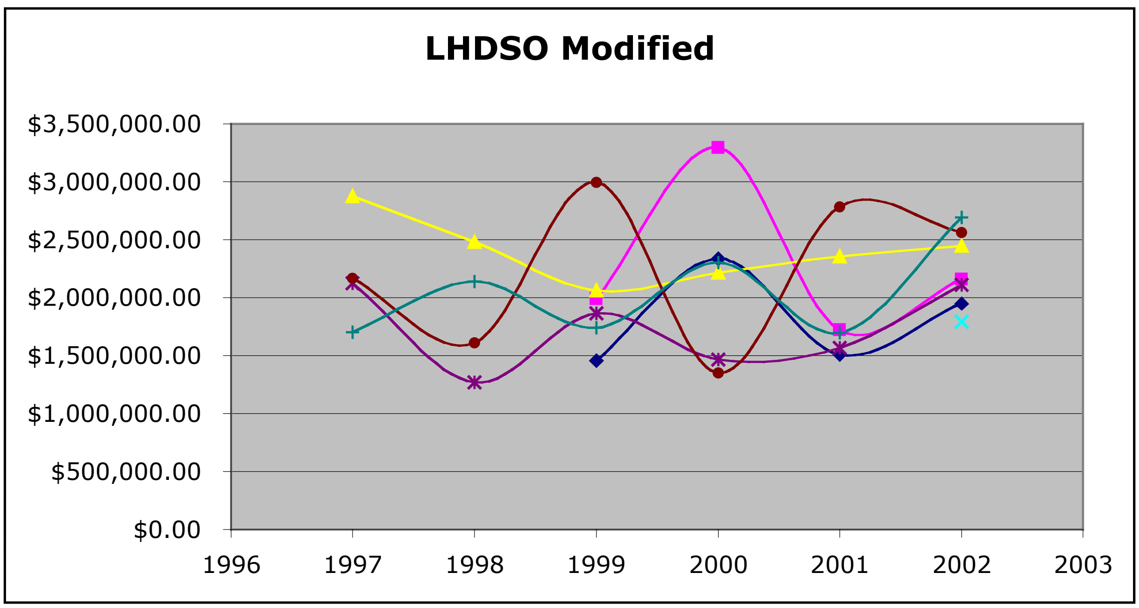

Figure 55. LHD SO After Data Groom

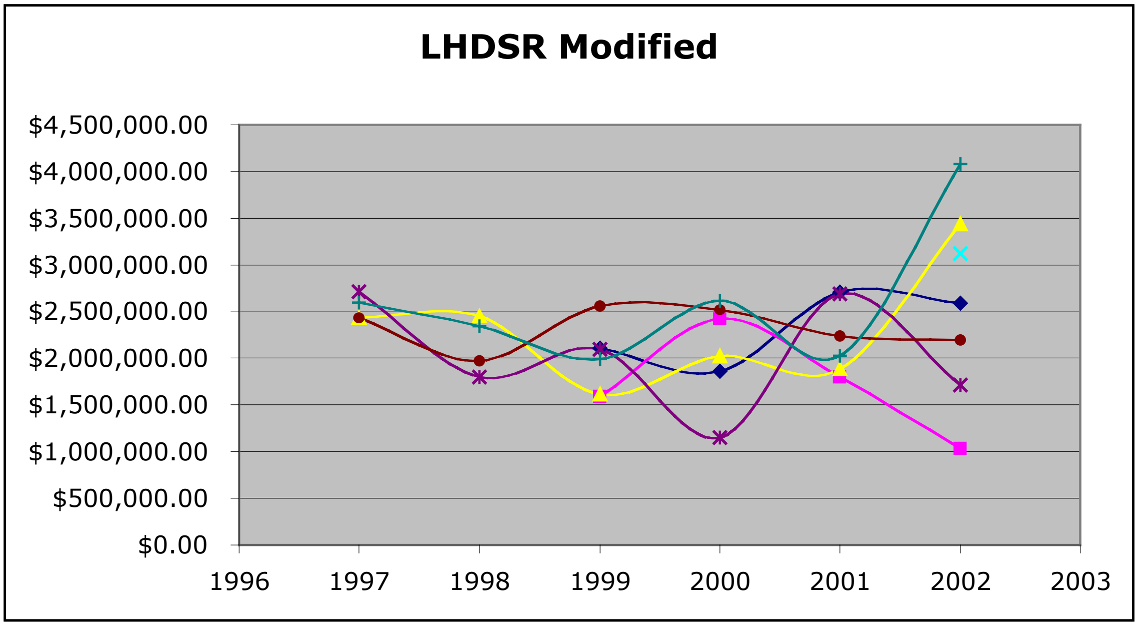

Figure 56. LHD SR After Data Groom

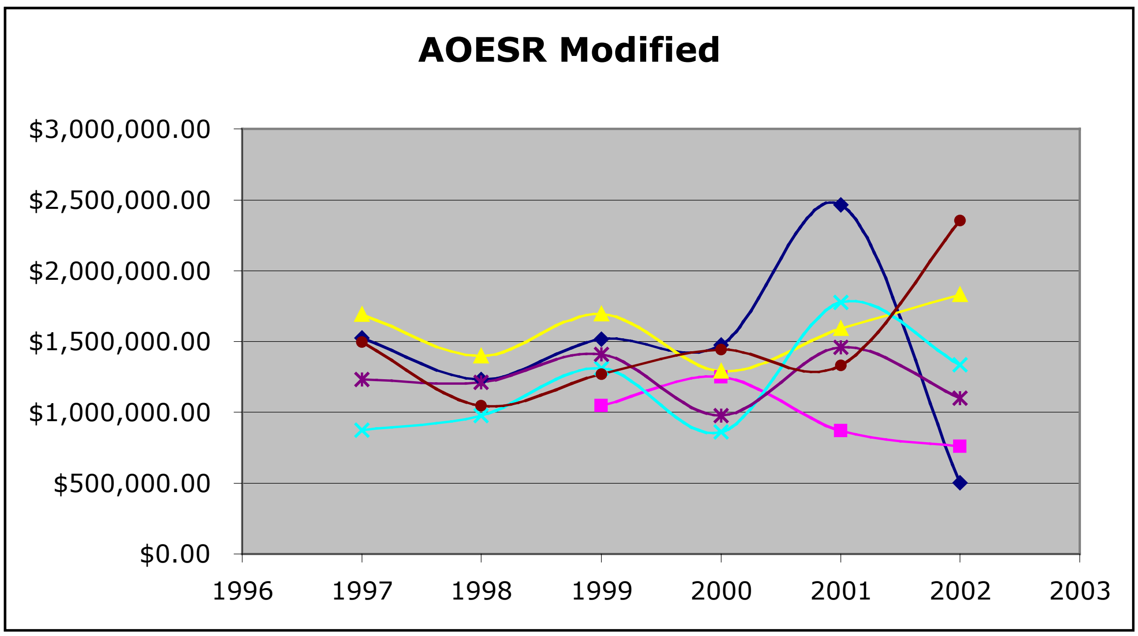

Figure 57. AOE SR After Data Groom

APPENDIX D: ANOVA FOLLOWING DATA GROOM

The following are the results of the ANOVA tests run after the data groom. Notice, every class of ship in each cost code demonstrates no significant differences except for the CV.

CV/SF

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.3557E+15	9	3.7286E+14	17.2484598	4.9587E-11	2.13059792
Within Groups	8.4305E+14	39	2.1617E+13			
Total	4.1988E+15	48				

CV/SO

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.857E+14	11	2.5973E+13	4.69499633	4.9345E-05	1.96754613
Within Groups	3.0426E+14	55	5.532E+12			
Total	5.8996E+14	66				

CV/SU

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.2718E+12	9	1.4131E+11	0.48944246	0.87244884	2.13752571
Within Groups	1.0971E+13	38	2.8871E+11			
Total	1.2243E+13	47				

CV/SR

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.163E+14	11	1.0573E+13	1.78427353	0.08040121	1.97451655
Within Groups	3.1405E+14	53	5.9255E+12			
Total	4.3035E+14	64				

CG/SR

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9.6317E+12	22	4.378E+11	0.95631767	0.52392092	1.63812963
Within Groups	5.1274E+13	112	4.578E+11			
Total	6.0905E+13	134				

Figure 58. CV and CG ANOVA Results After Data Groom

FFG/SO

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.3297E+12	25	5.3189E+10	1.53105847	0.06671941	1.59499081
Within Groups	4.3077E+12	124	3.474E+10			
Total	5.6374E+12	149				

FFG/SR

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.9235E+12	25	1.1694E+11	0.94907861	0.53902132	1.59499081
Within Groups	1.5278E+13	124	1.2321E+11			
Total	1.8202E+13	149				

FFG/SU

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.3898E+11	26	1.6884E+10	1.19068138	0.26231617	1.59747948
Within Groups	1.5456E+12	109	1.418E+10			
Total	1.9846E+12	135				

DD/SO

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.3744E+12	20	6.8719E+10	1.65911616	0.05418086	1.67973369
Within Groups	4.0176E+12	97	4.1419E+10			
Total	5.392E+12	117				

DD/SR

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.6614E+12	20	2.8307E+11	1.14366355	0.31934	1.67434422
Within Groups	2.5246E+13	102	2.4751E+11			
Total	3.0907E+13	122				

Figure 59. FFG and DD ANOVA Results After Data Groom

LSD/SF

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.6154E+12	14	4.011E+11	0.94033508	0.52230609	1.85203675
Within Groups	2.6873E+13	63	4.2655E+11			
Total	3.2488E+13	77				

LSD/SR

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.5123E+11	14	6.0802E+10	0.91475944	0.54746989	1.8400037
Within Groups	4.5198E+12	68	6.6468E+10			
Total	5.371E+12	82				

LHD/SO

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.0851E+12	6	3.4751E+11	1.51479489	0.21258206	2.47410981
Within Groups	5.9647E+12	26	2.2941E+11			
Total	8.0498E+12	32				

LHD/SR

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3.0602E+12	6	5.1003E+11	1.54102771	0.20439658	2.47410981
Within Groups	8.6051E+12	26	3.3097E+11			
Total	1.1665E+13	32				

AOE/SR

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.2916E+12	6	2.1527E+11	1.39515854	0.25258718	2.45911025
Within Groups	4.166E+12	27	1.543E+11			
Total	5.4576E+12	33				

Figure 60. LSD, LHD, and AOE ANOVA Results After Data Groom

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix E: Graphs of Ship Class / Cost CodE Expenditures

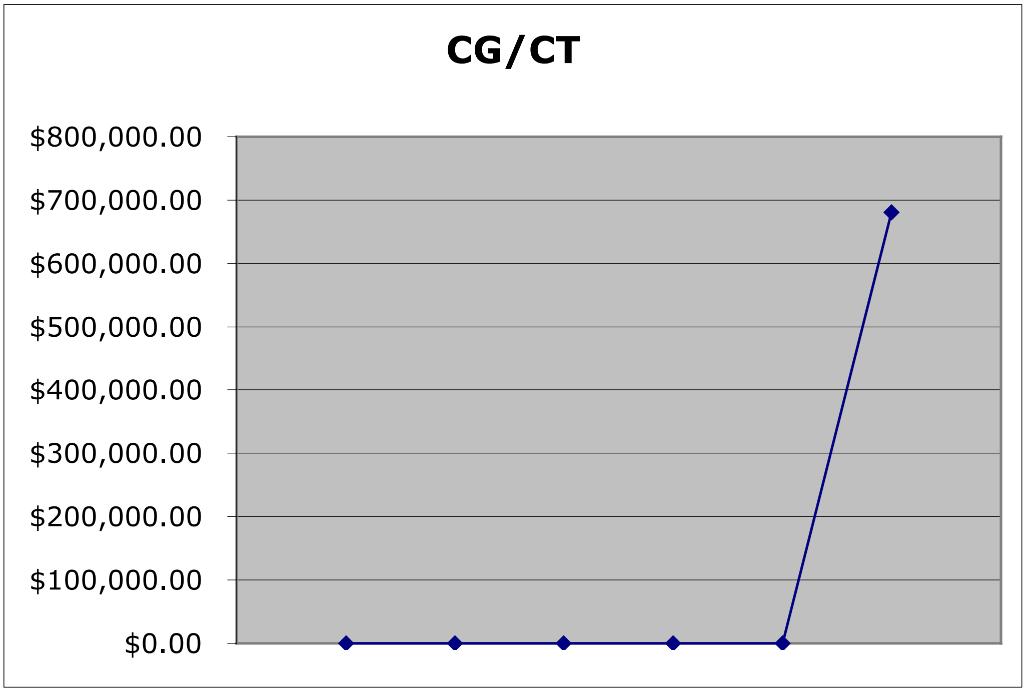

Figure 61. CG CT Expenditures by Year

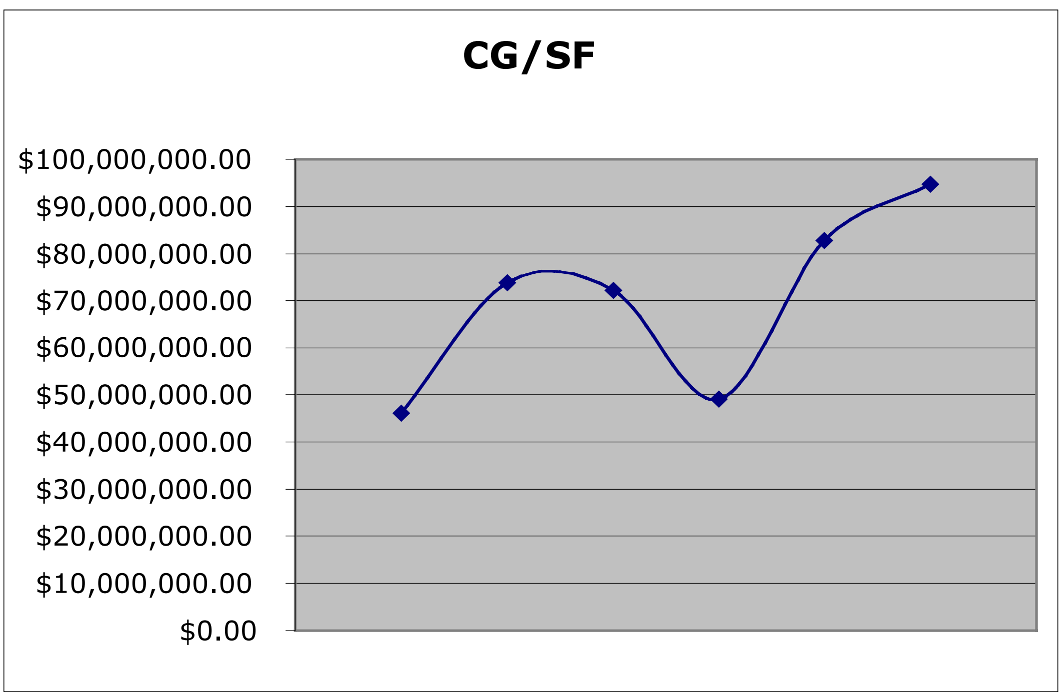

Figure 62. CG SF Expenditures by Year

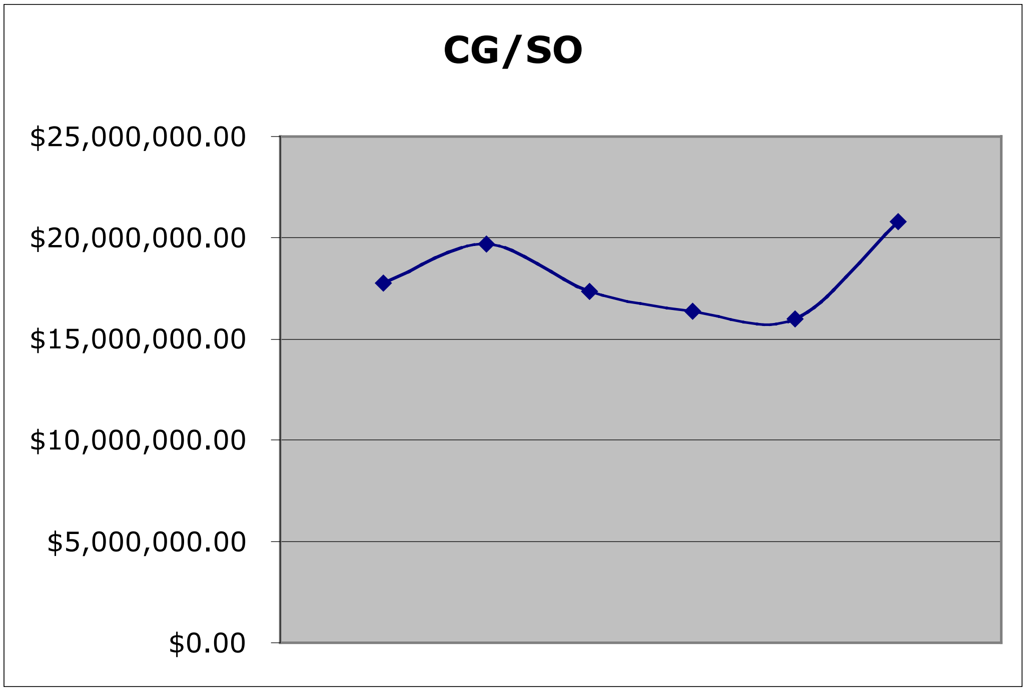

Figure 63. CG SO Expenditures by Year

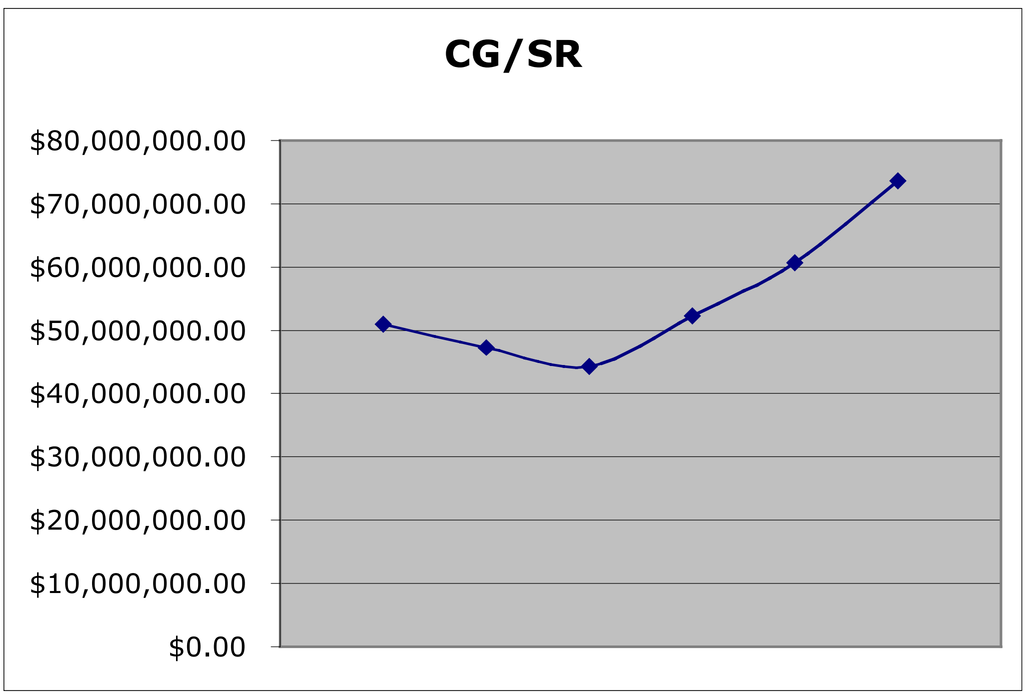

Figure 64. CG SR Expenditures by Year

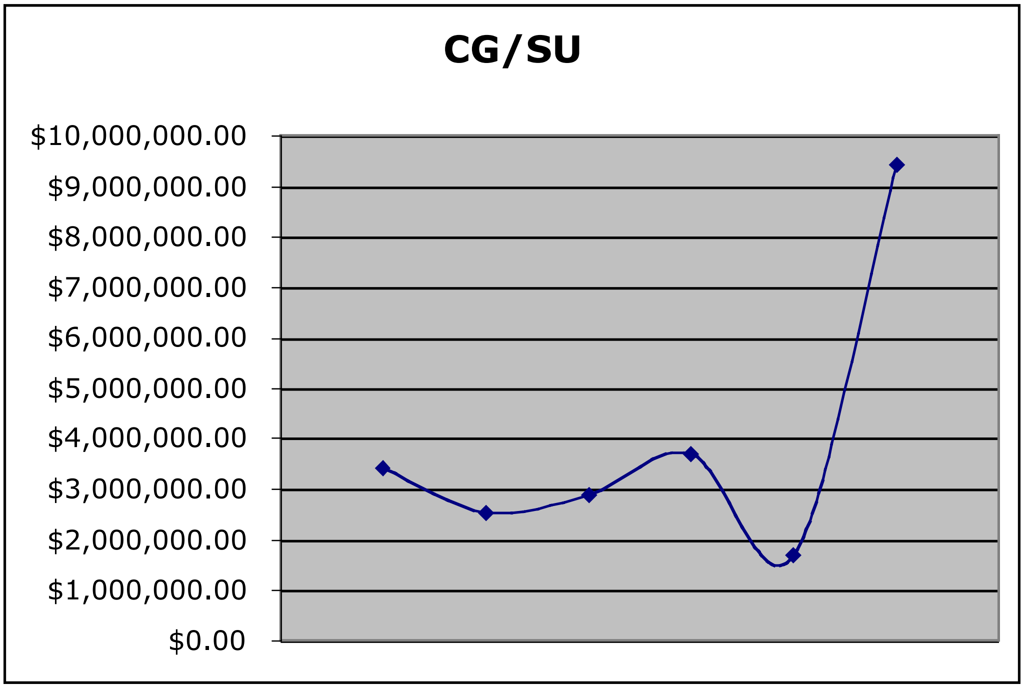

Figure 65. CG SU Expenditures by Year

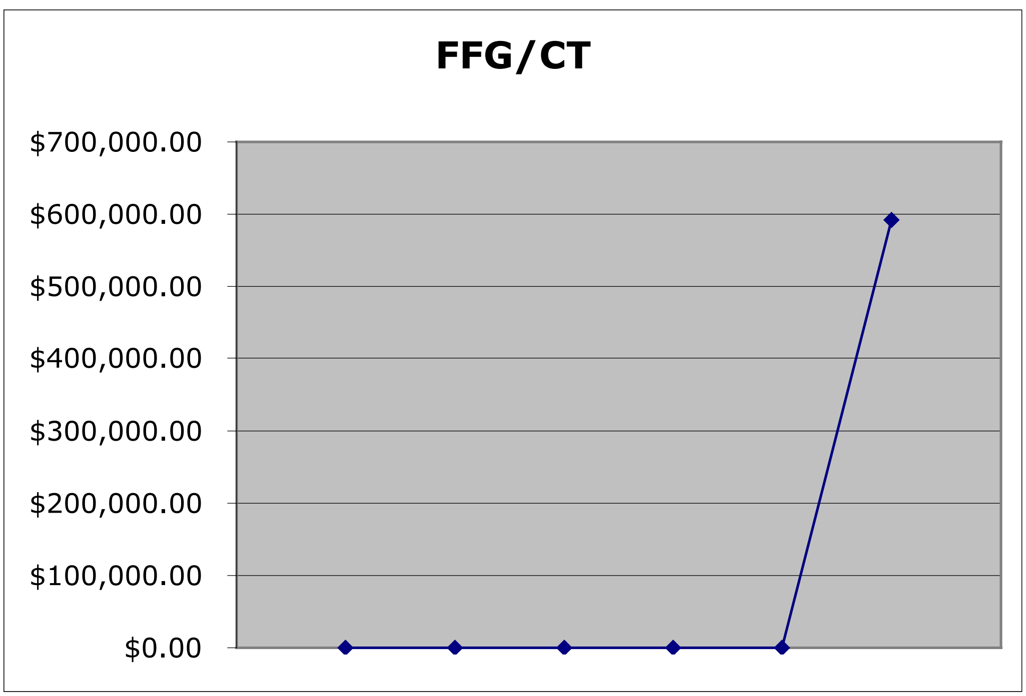

Figure 66. FFG CT Expenditures by Year

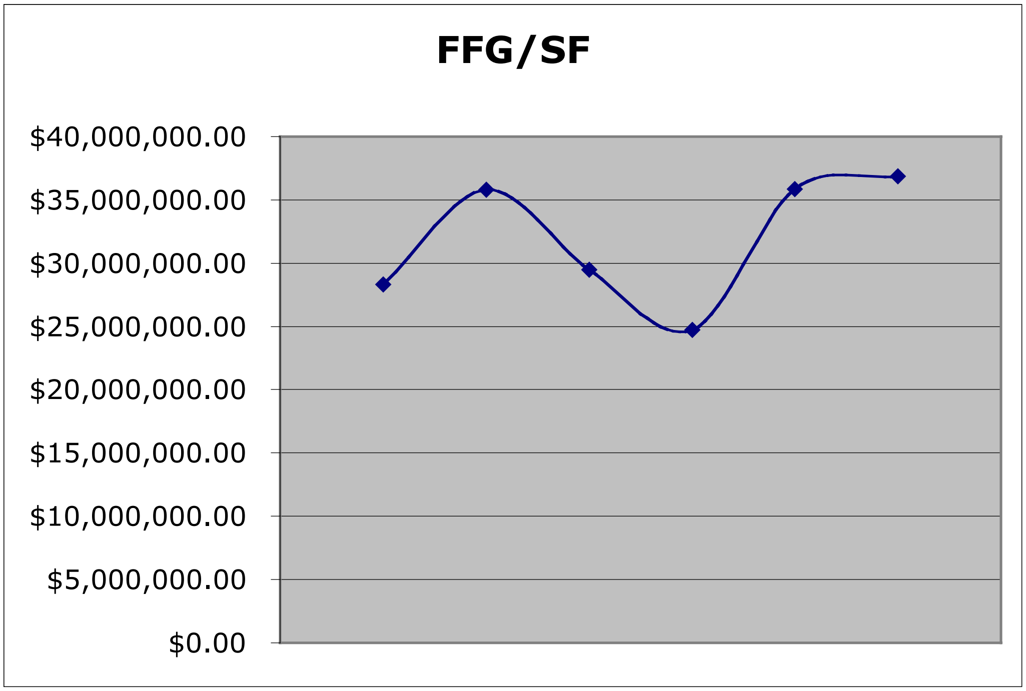

Figure 67. FFG SF Expenditures by Year

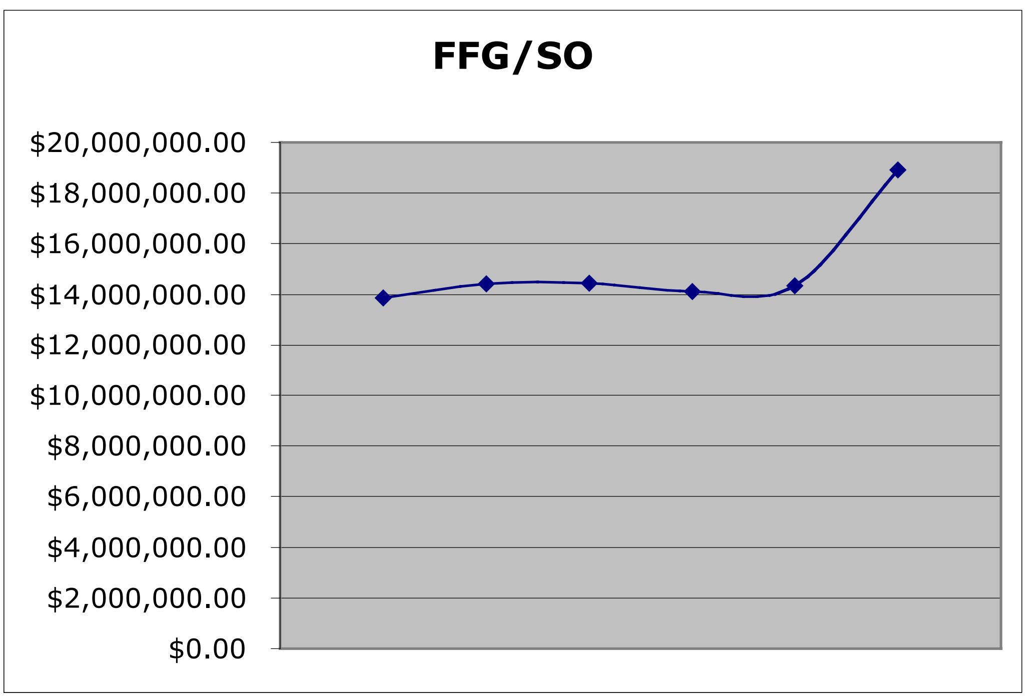

Figure 68. FFG SO Expenditures by Year

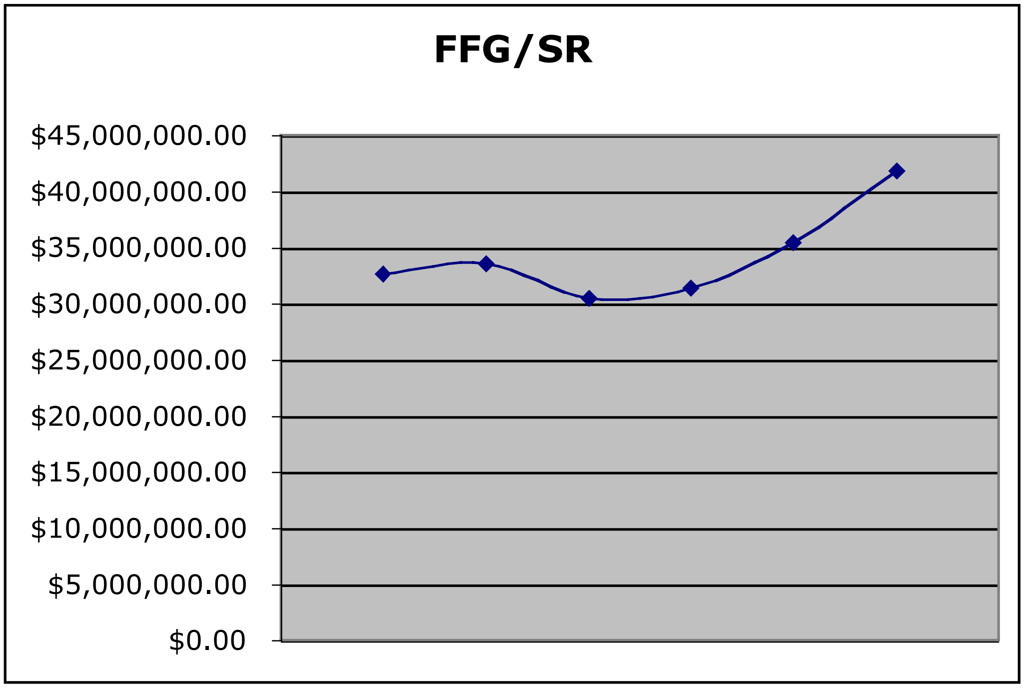

Figure 69. FFG SR Expenditures by Year

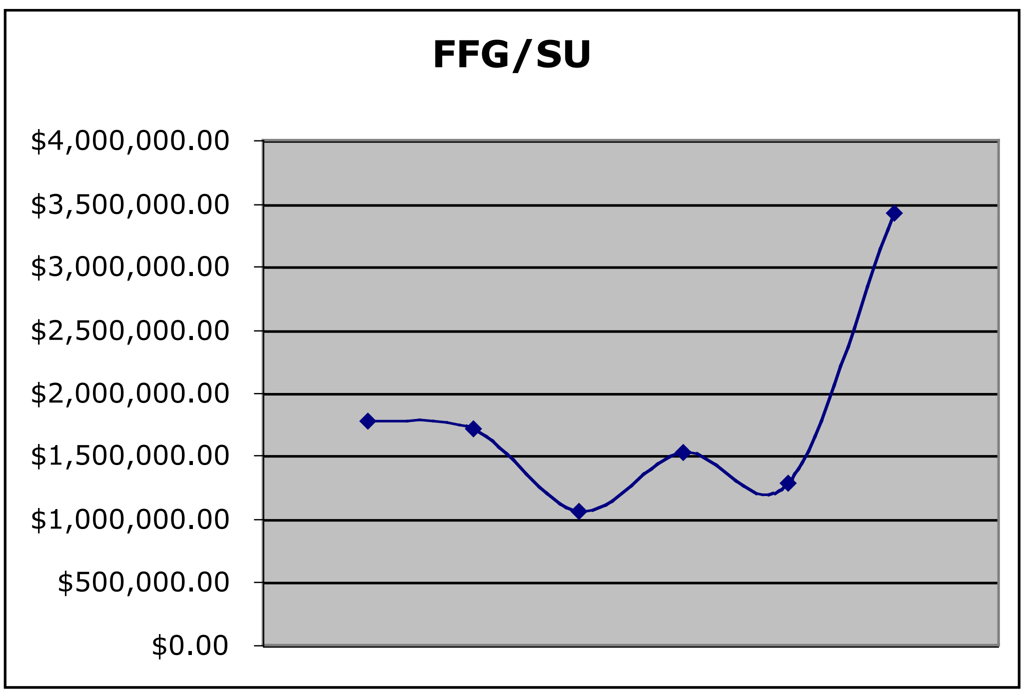

Figure 70. FFG SU Expenditures by Year

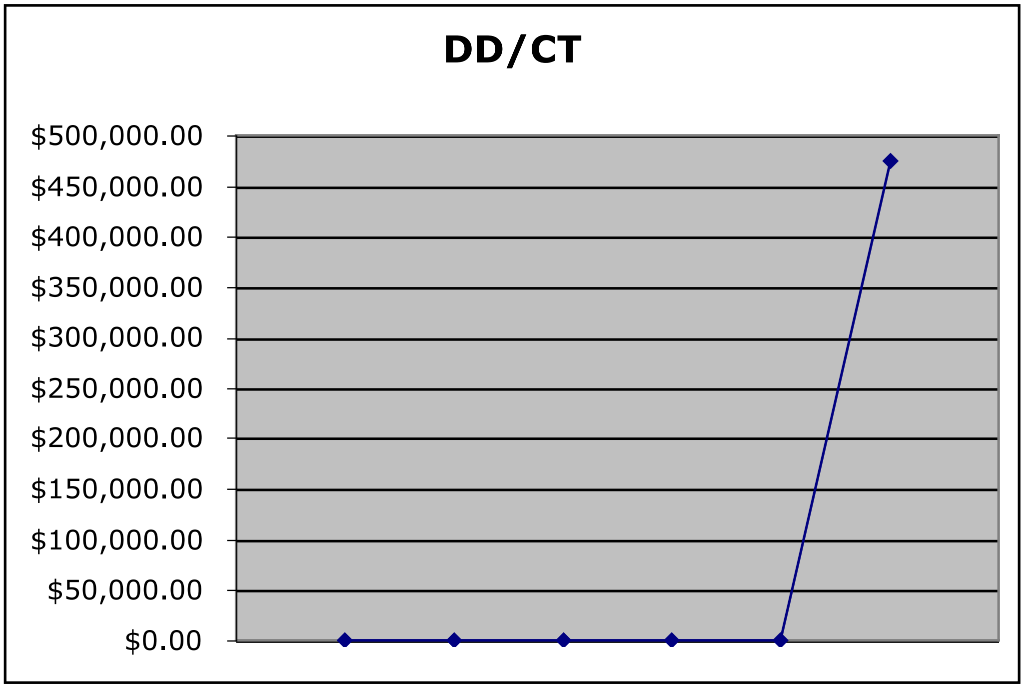

Figure 71. DD CT Expenditures by Year

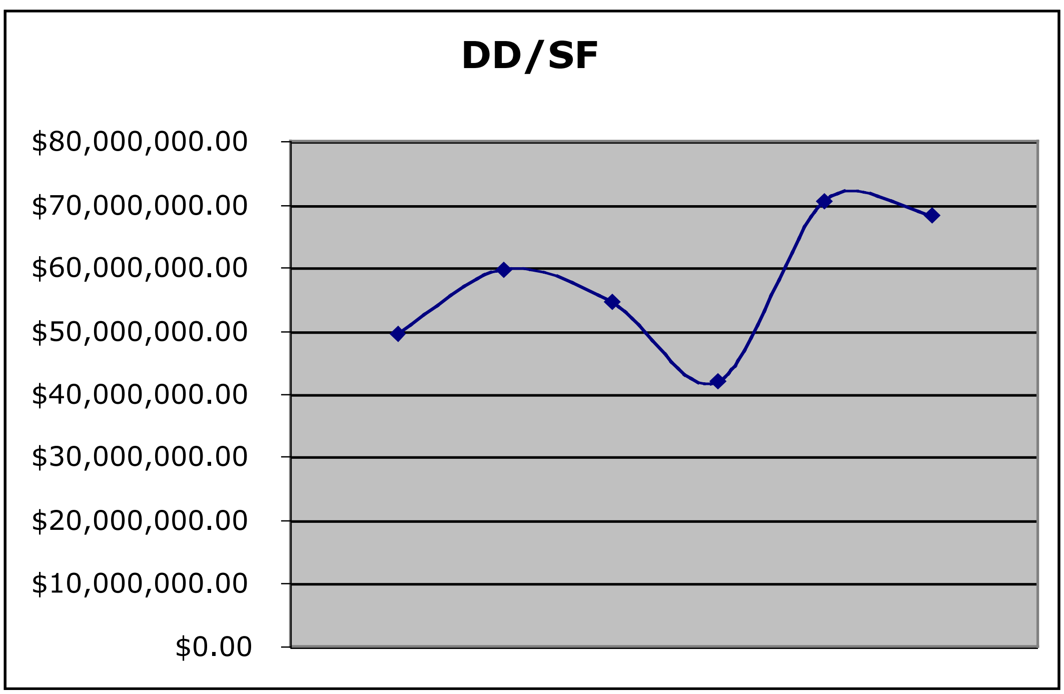

Figure 72. DD SF Expenditures by Year

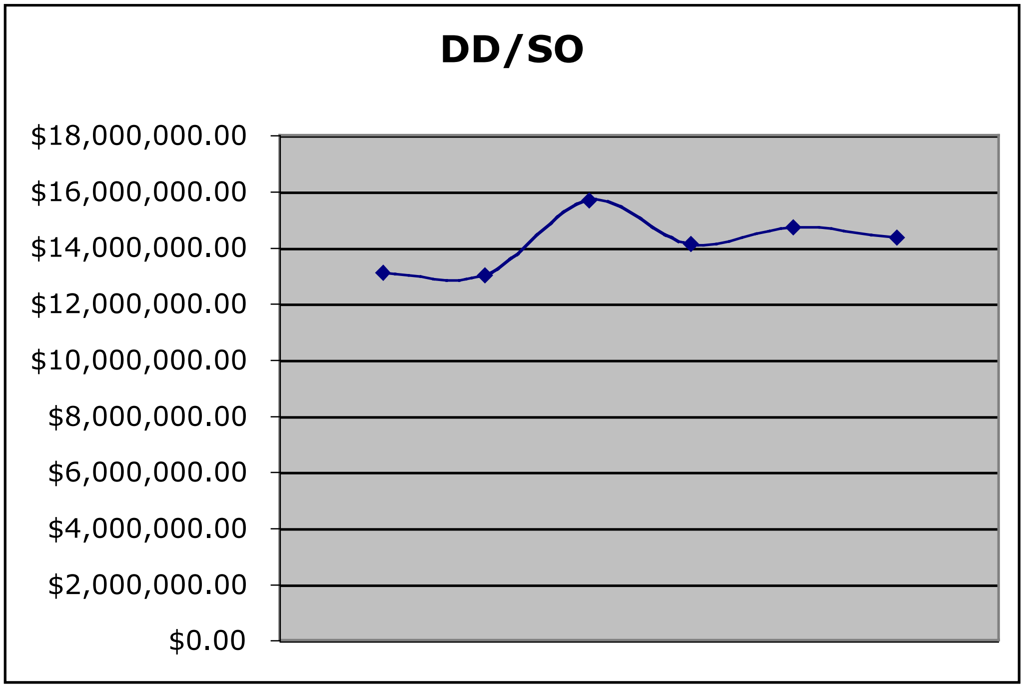

Figure 73. DD SO Expenditures by Year

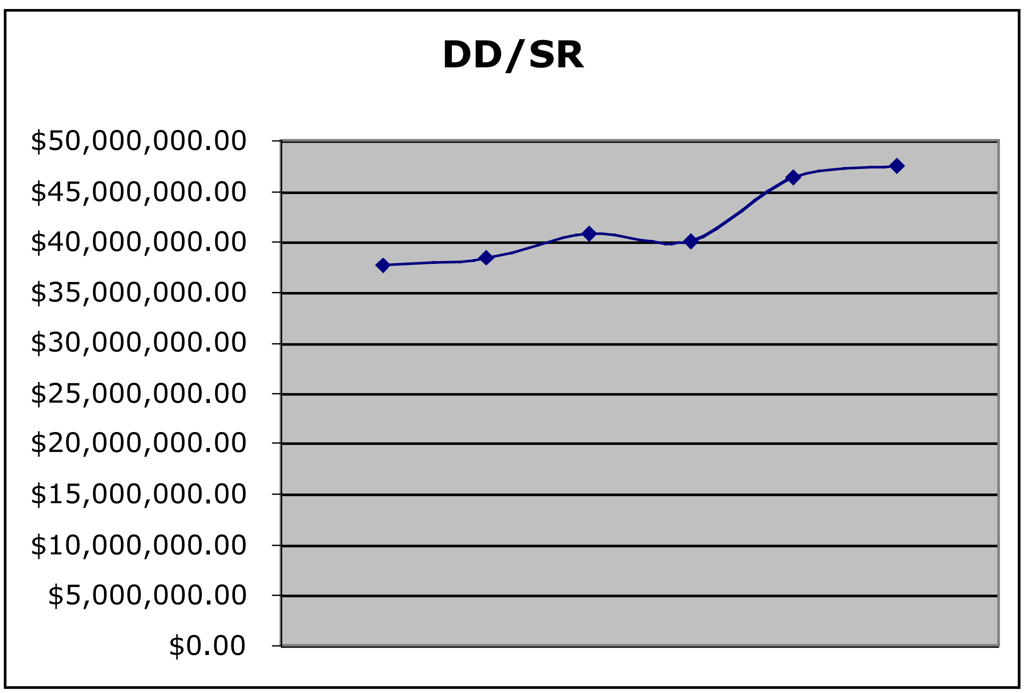

Figure 74. DD SR Expenditures by Year

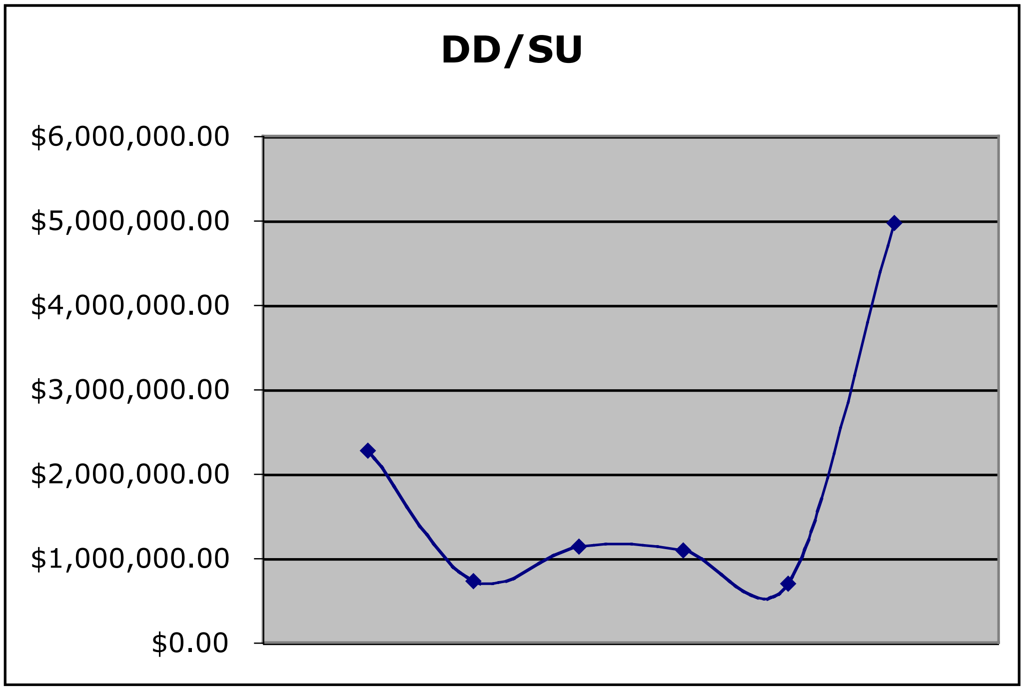

Figure 75. DD SU Expenditures by Year

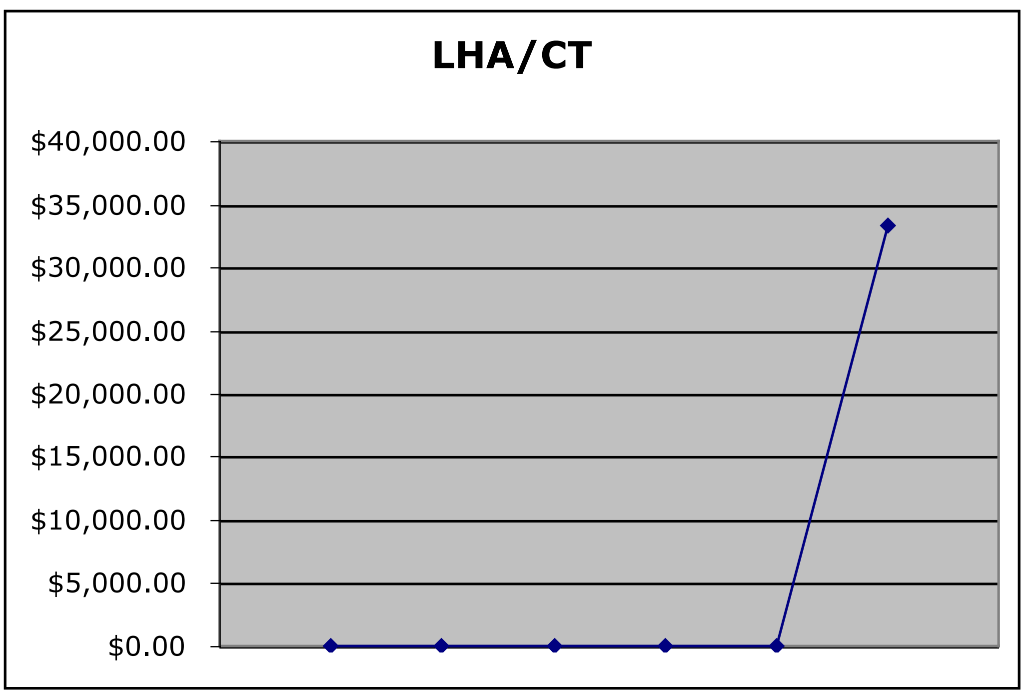

Figure 76. LHA CT Expenditures by Year

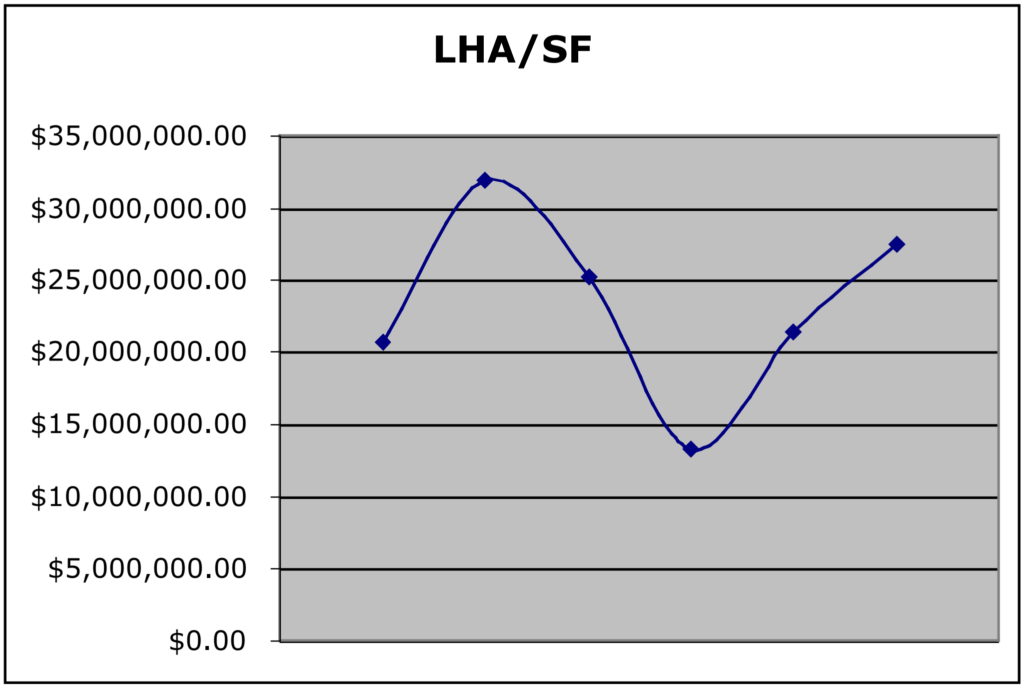

Figure 77. LHA SF Expenditures by Year

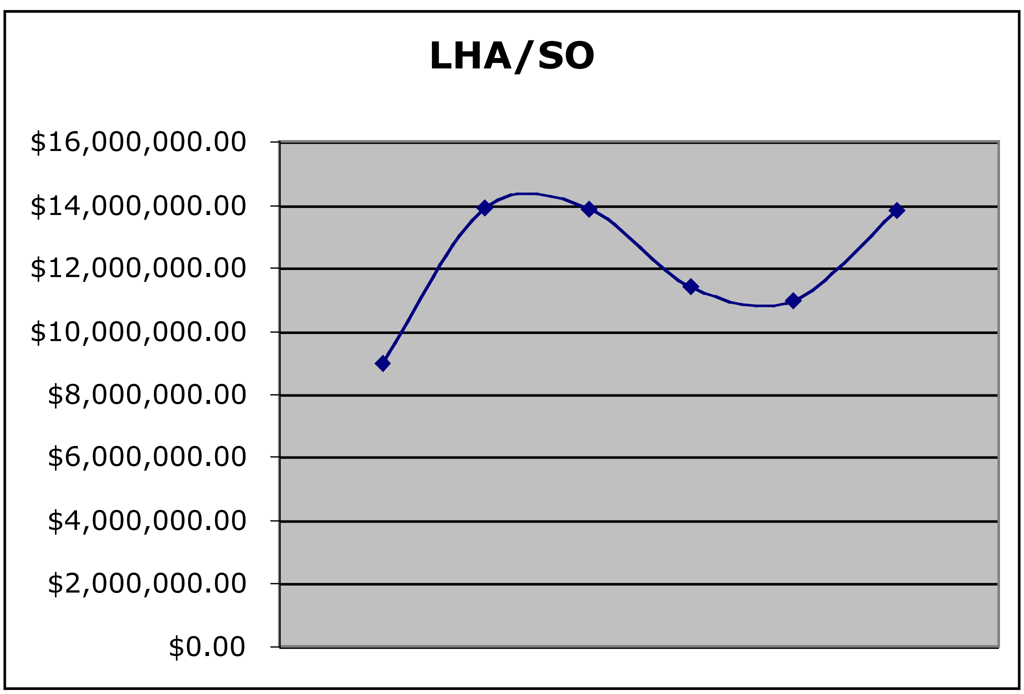

Figure 78. LHA SO Expenditures by Year

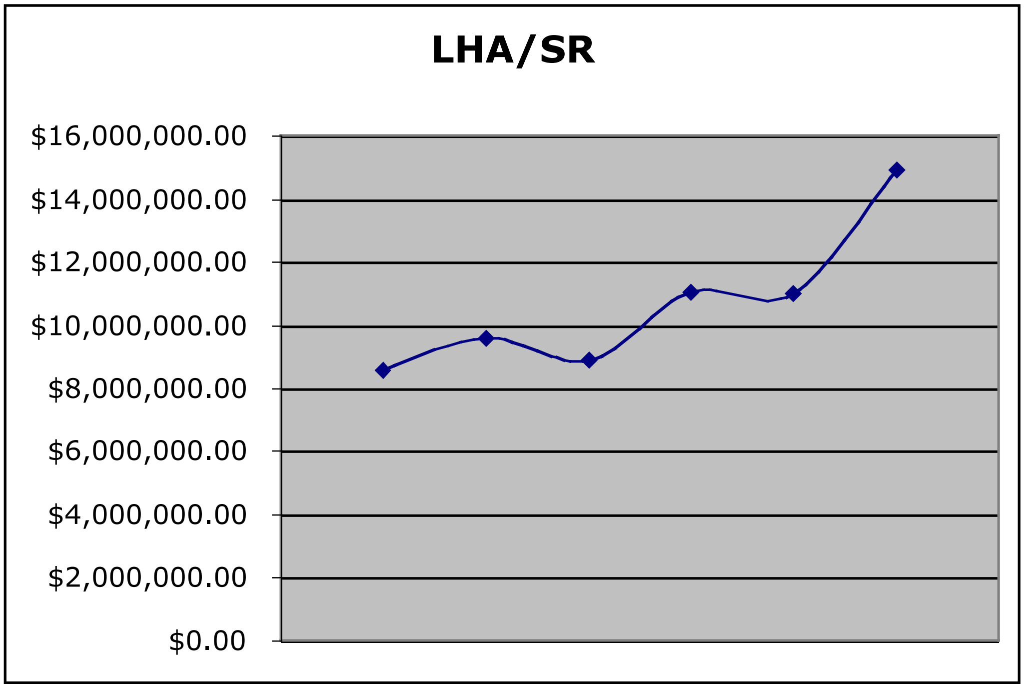

Figure 79. LHA SR Expenditures by Year

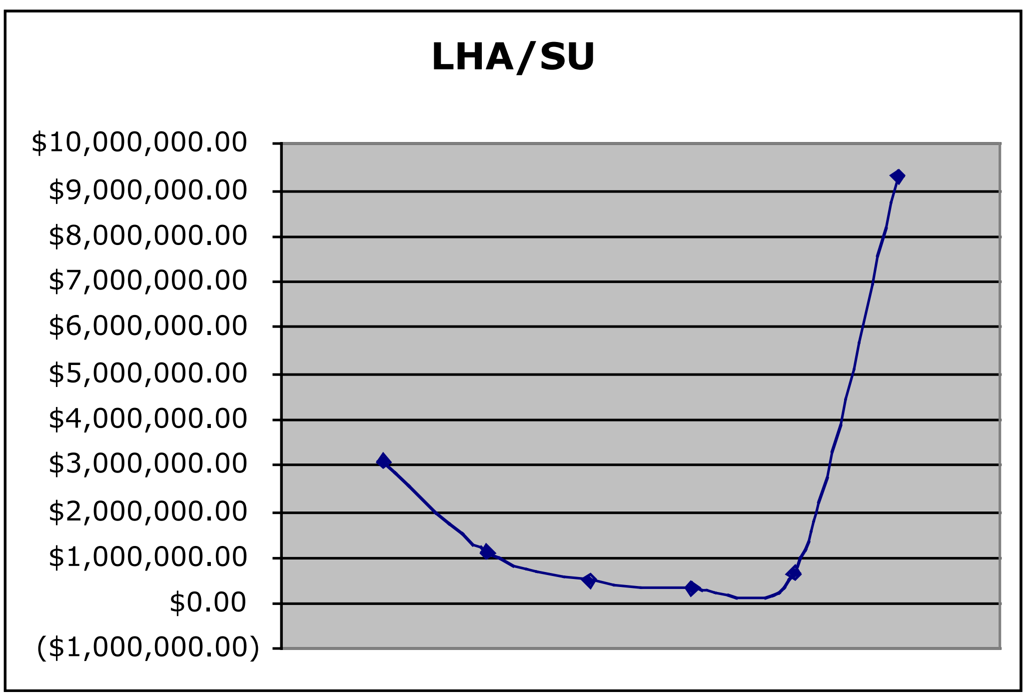

Figure 80. LHA SU Expenditures by Year

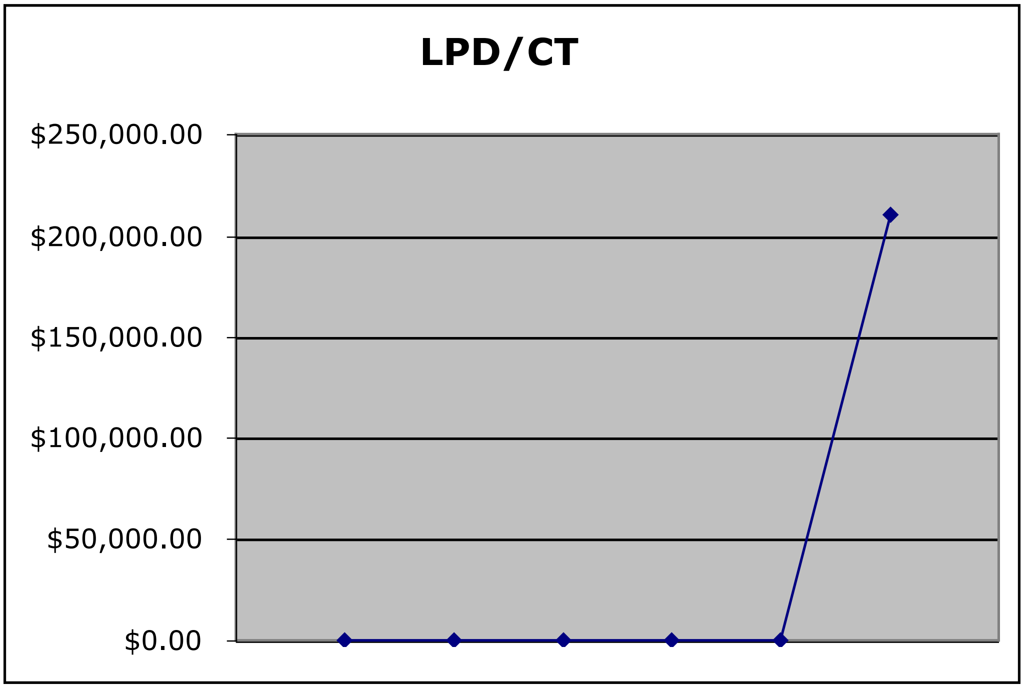

Figure 81. LPD CT Expenditures by Year

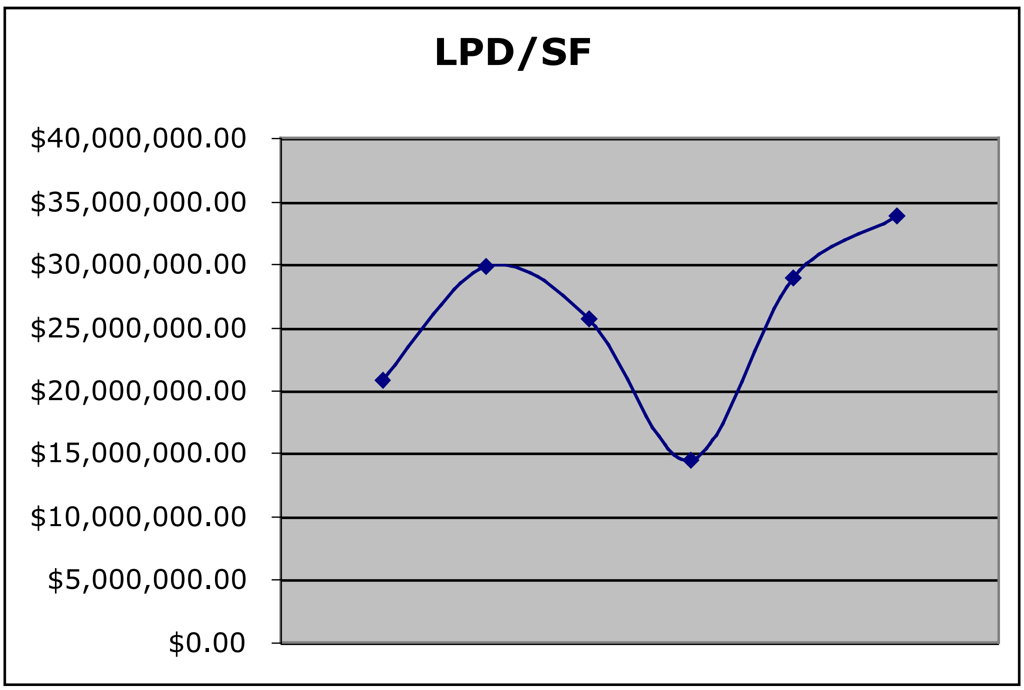

Figure 82. LPD SF Expenditures by Year

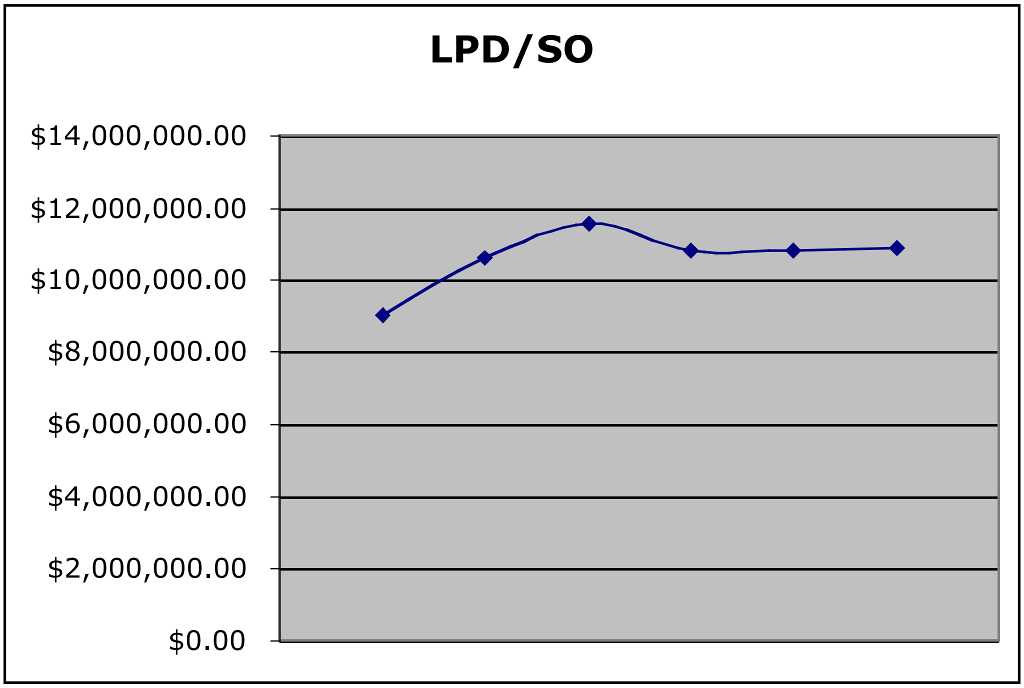

Figure 83. LPD SO Expenditures by Year

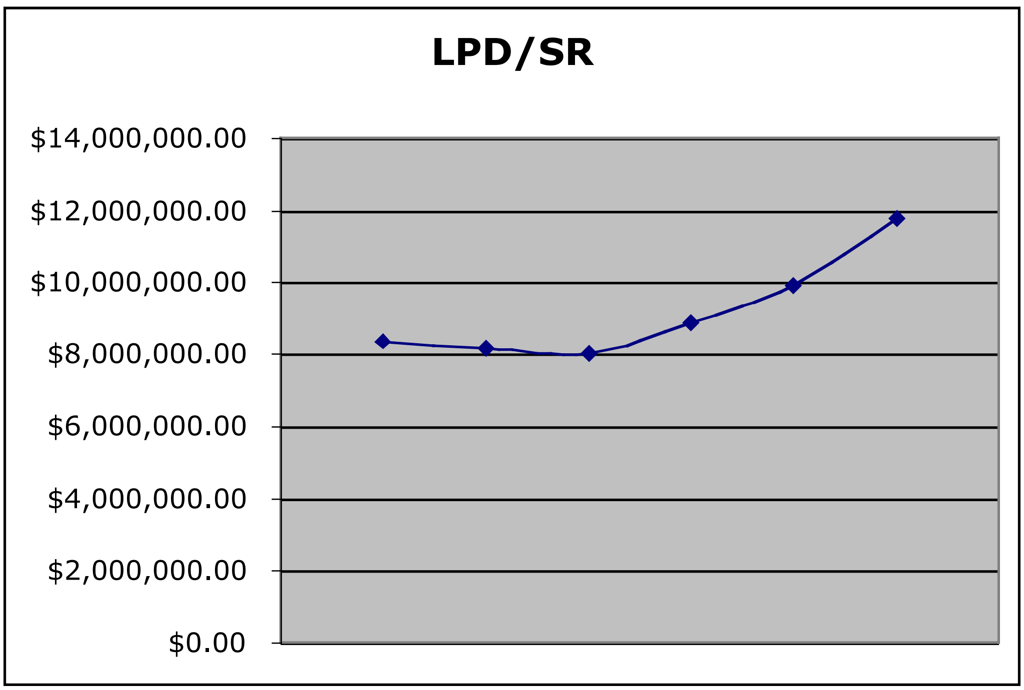

Figure 84. LPD SR Expenditures by Year

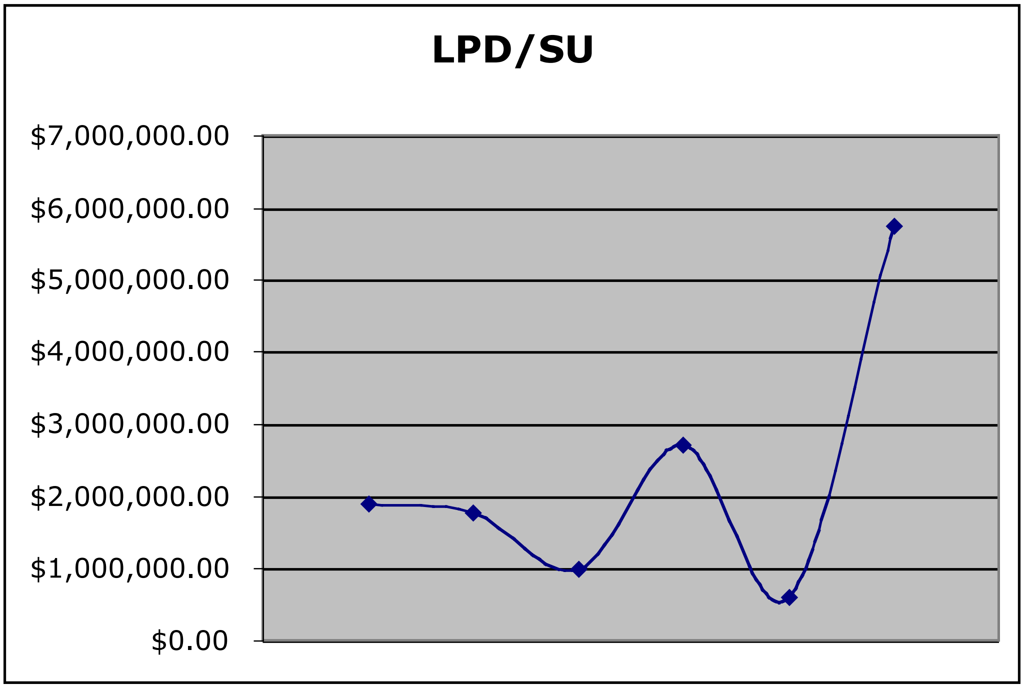

Figure 85. LPD SU Expenditures by Year

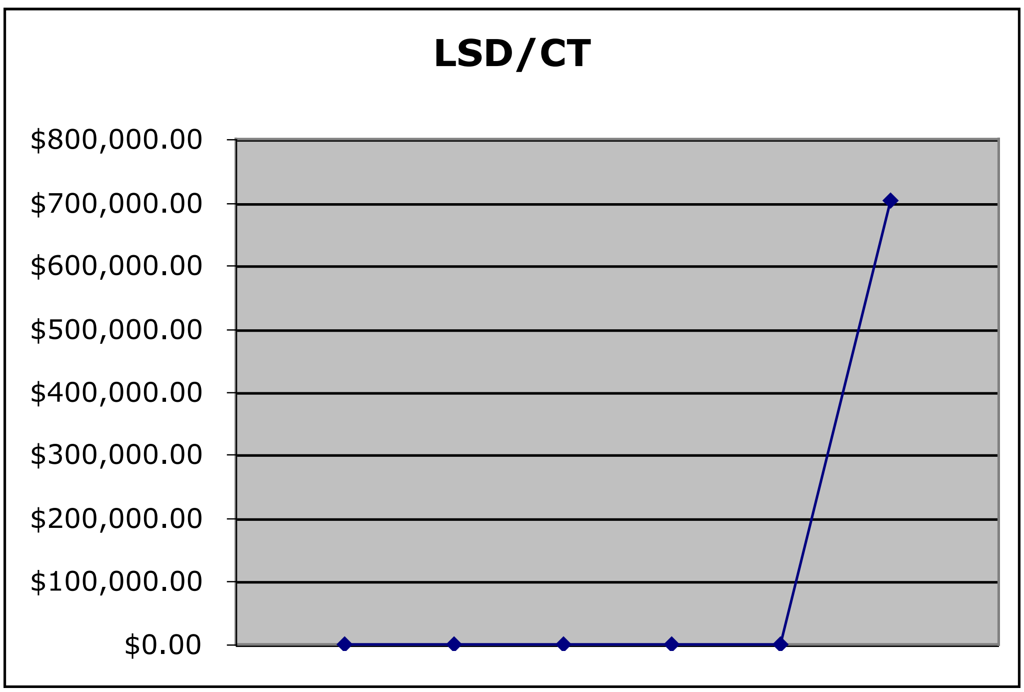

Figure 86. LSD CT Expenditures by Year

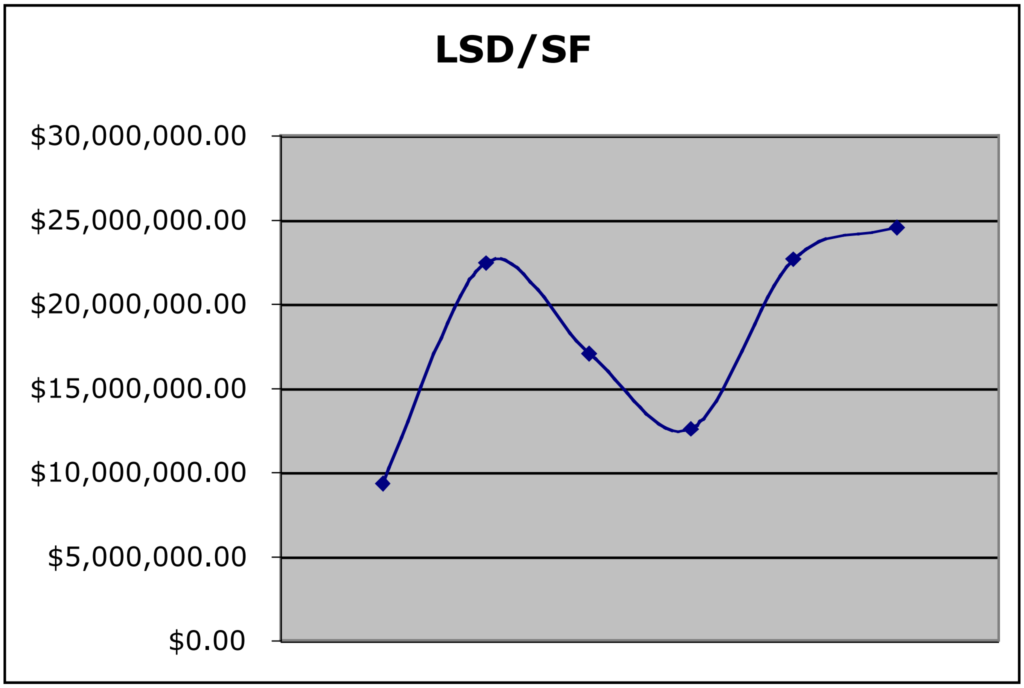

Figure 87. LSD SF Expenditures by Year

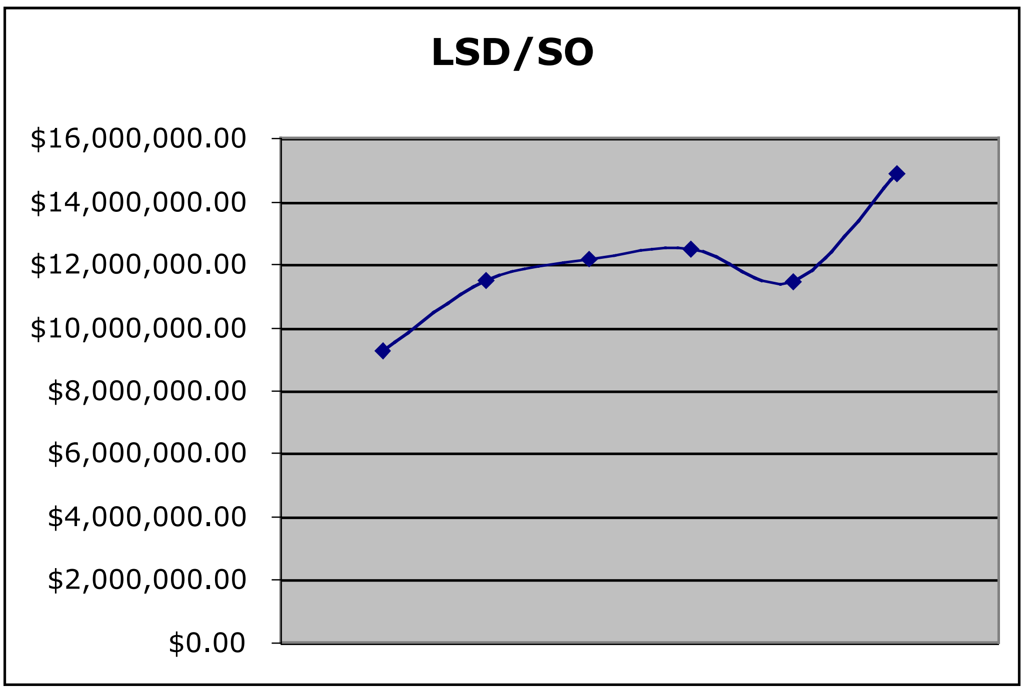

Figure 88. LSD SO Expenditures by Year

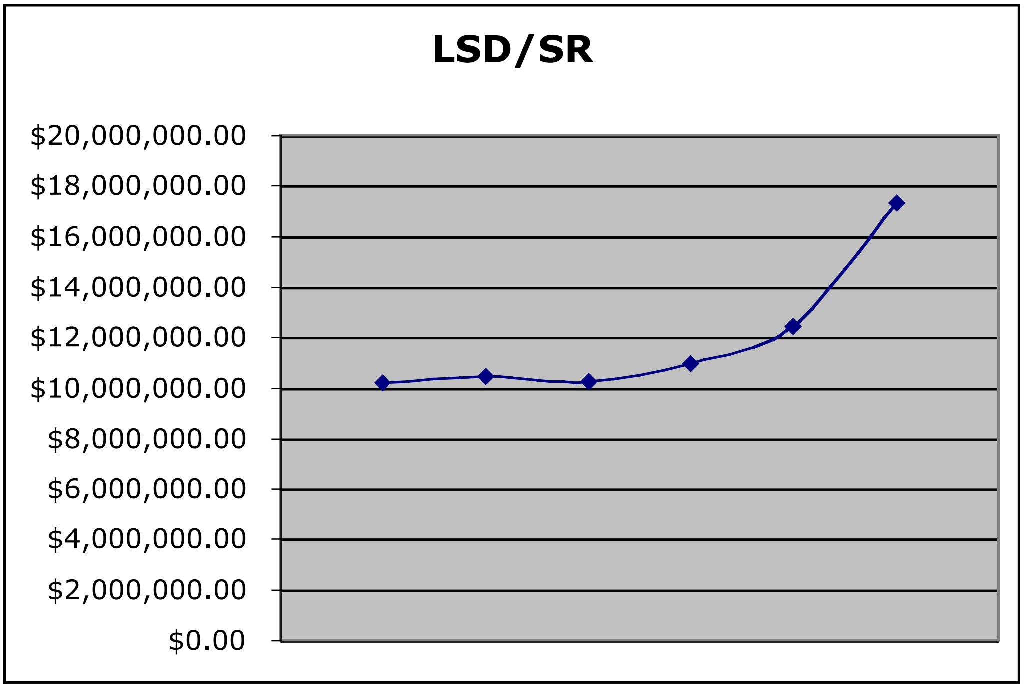

Figure 89. LSD SR Expenditures by Year

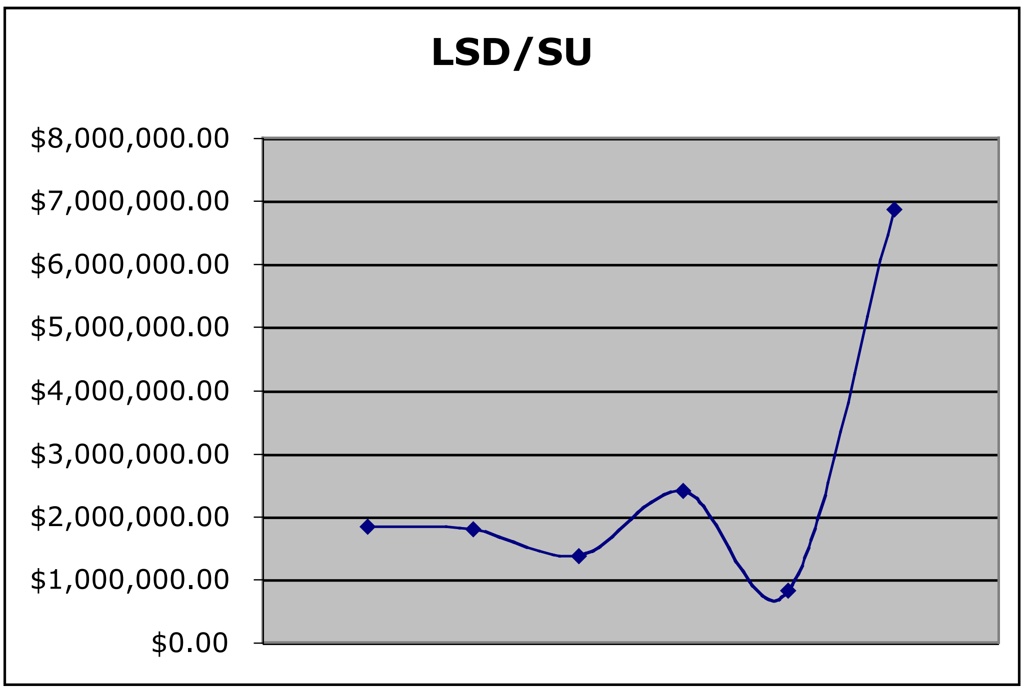

Figure 90. LSD SU Expenditures by Year

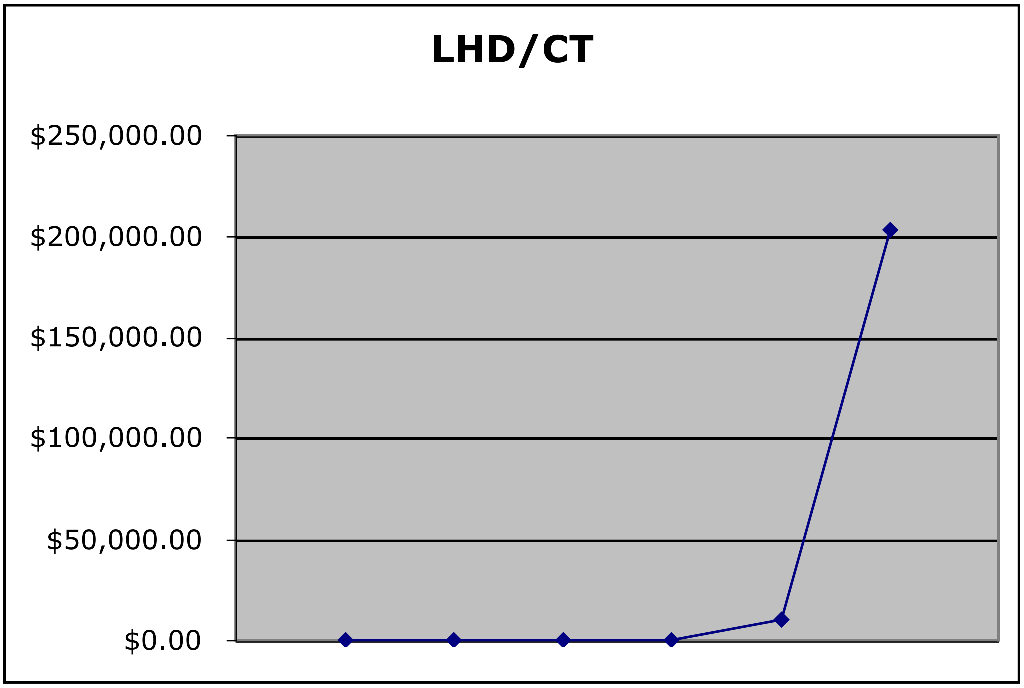

Figure 91. LHD CT Expenditures by Year

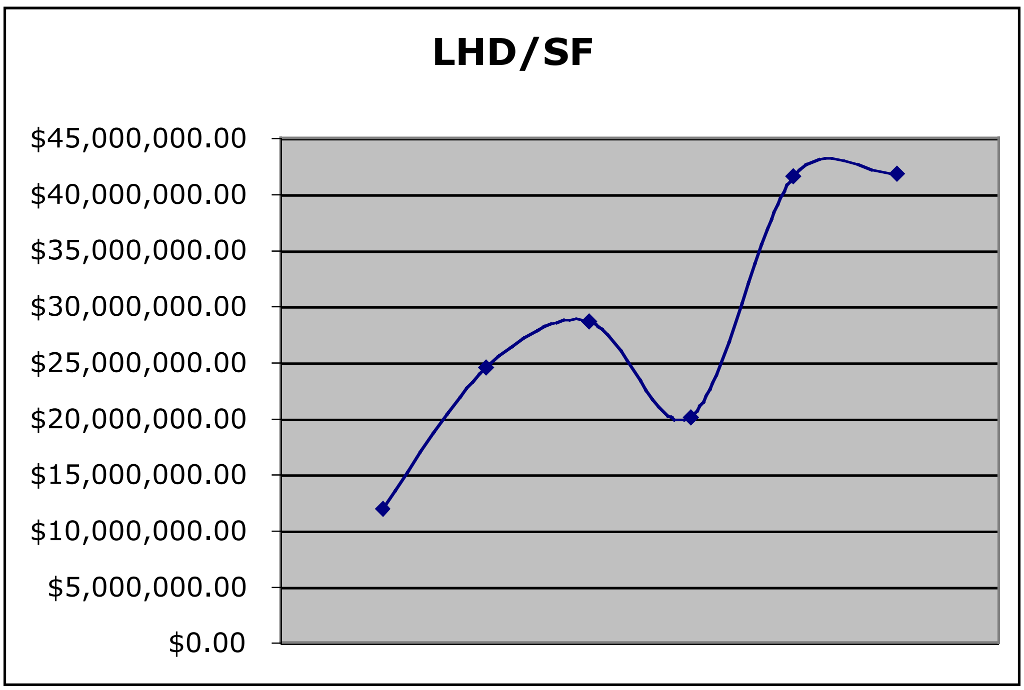

Figure 92. LHD SF Expenditures by Year

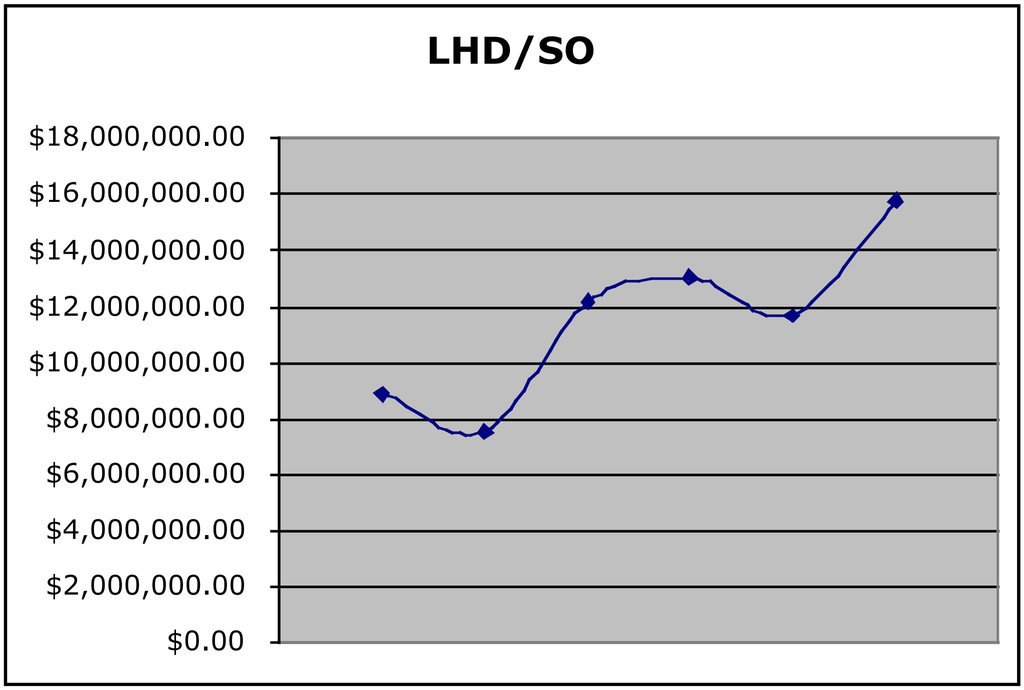

Figure 93. LHD SO Expenditures by Year

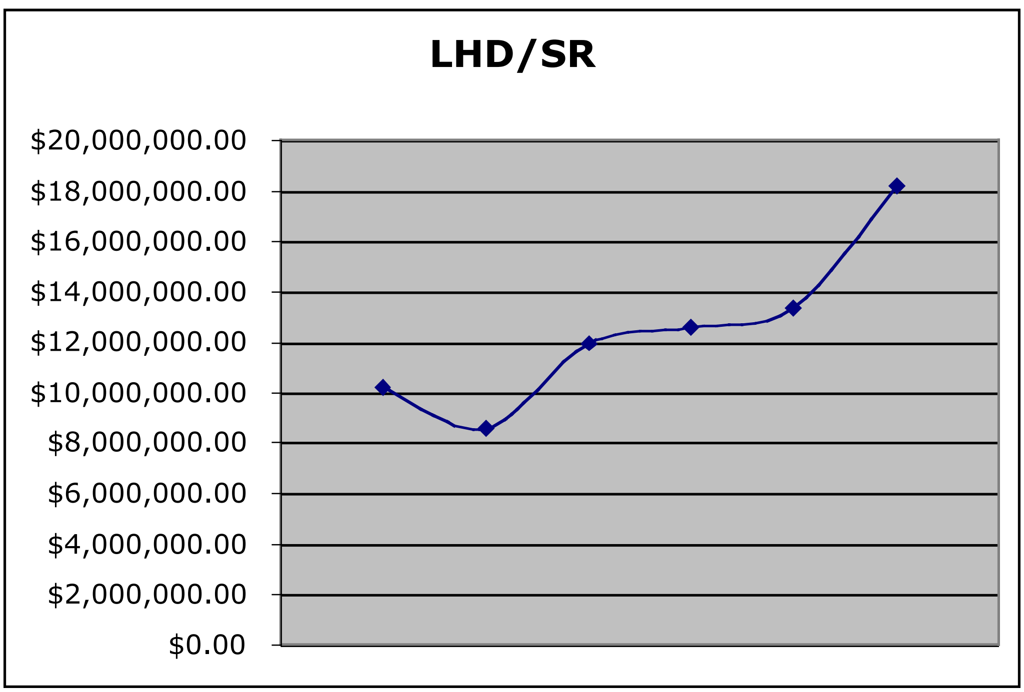

Figure 94. LHD SR Expenditures by Year

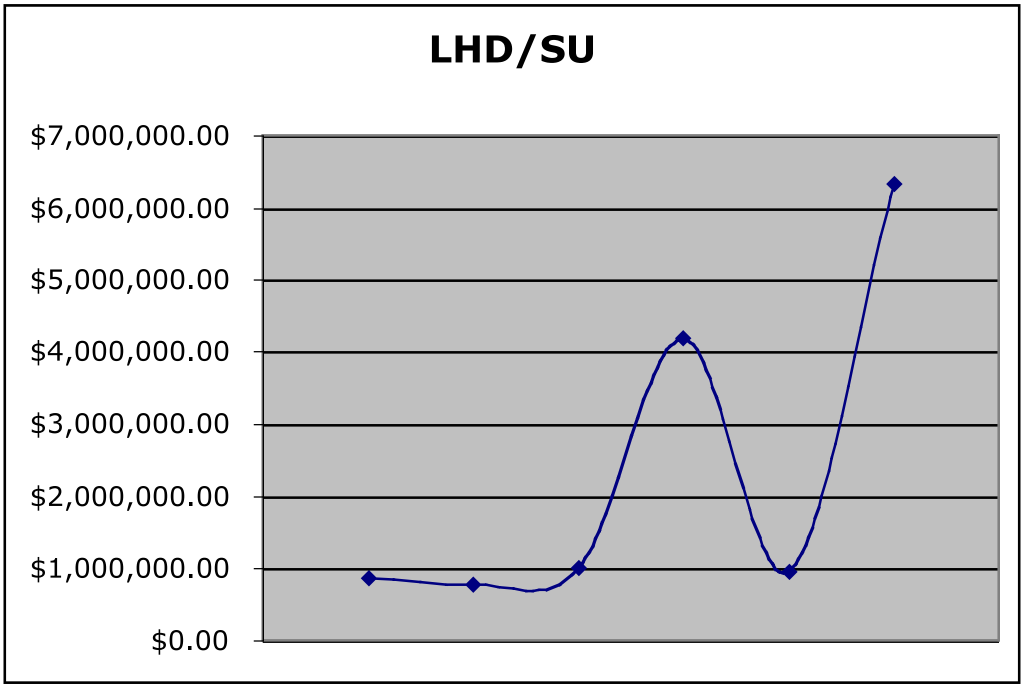

Figure 95. LHD SU Expenditures by Year

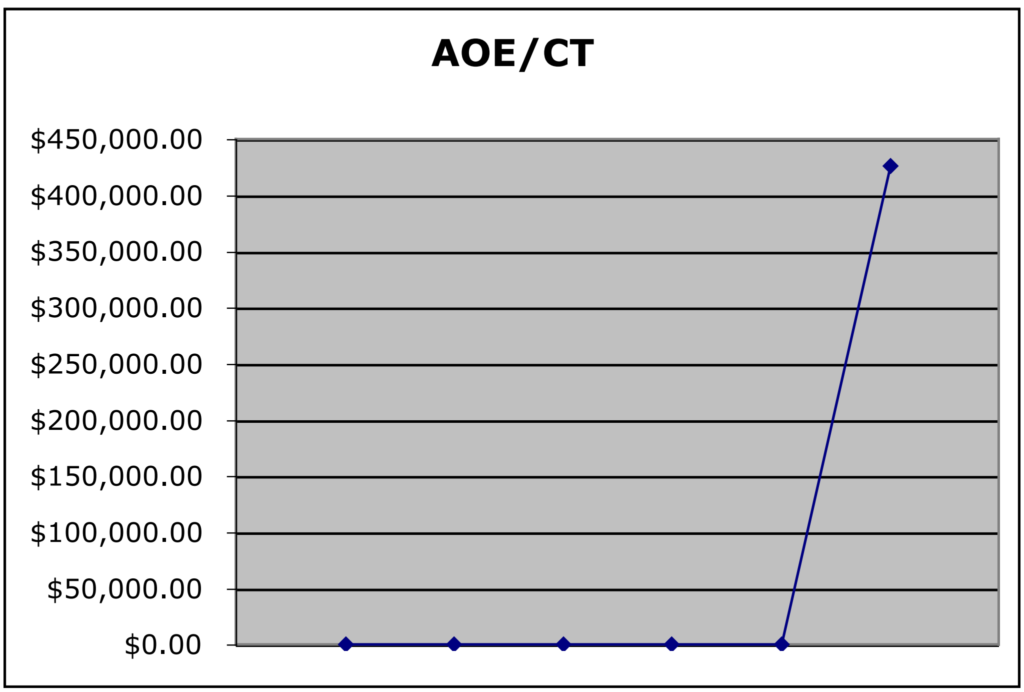

Figure 96. AOE CT Expenditures by Year

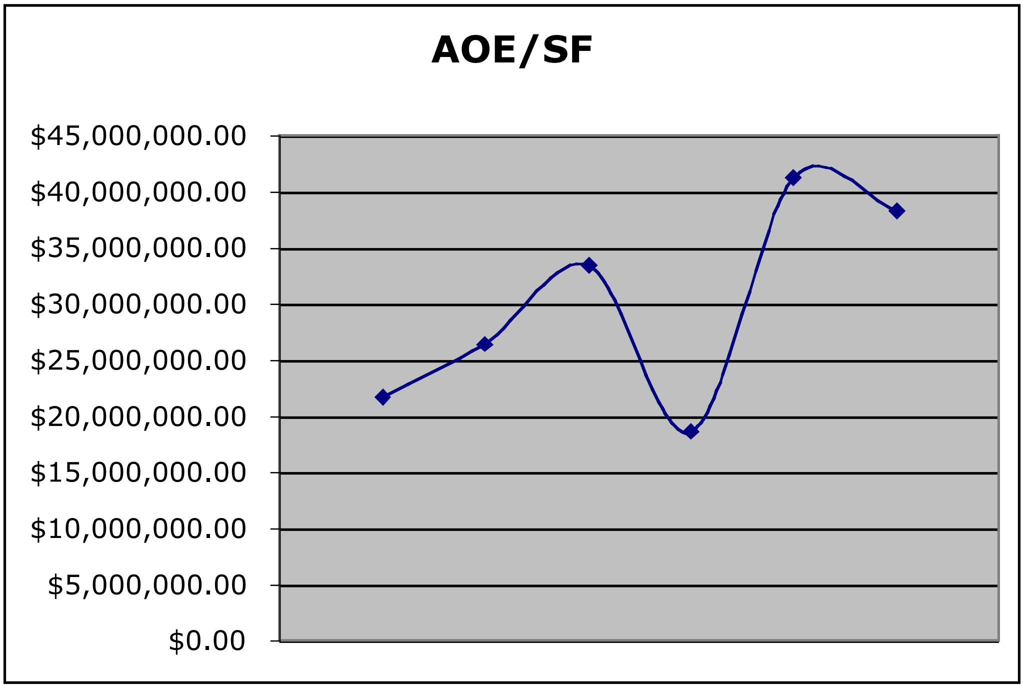

Figure 97. AOE SF Expenditures by Year

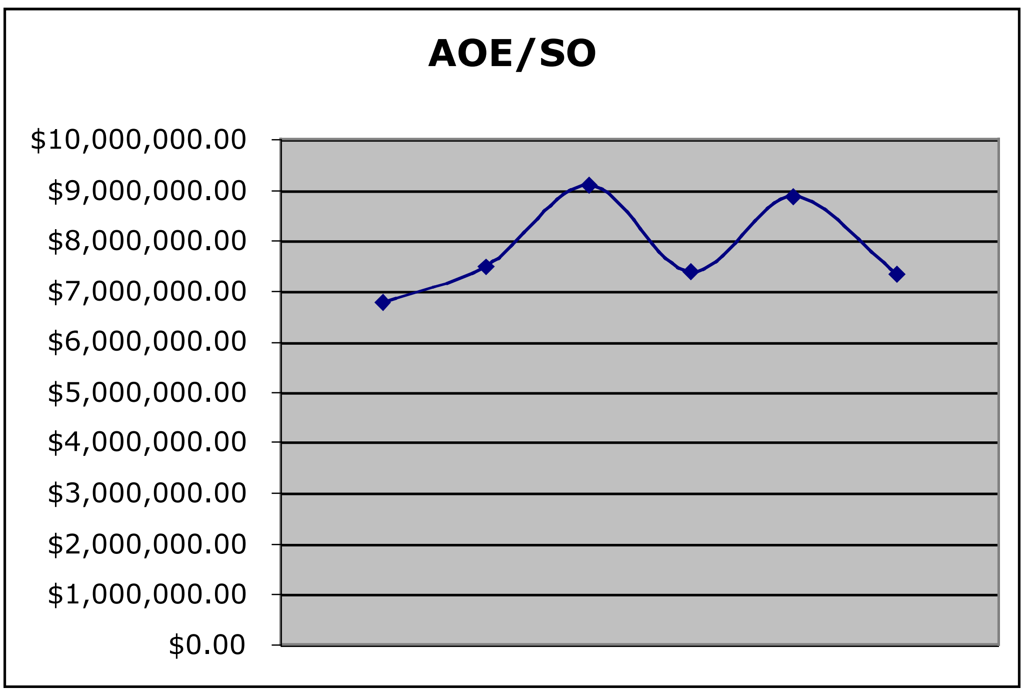

Figure 98. AOE SO Expenditures by Year

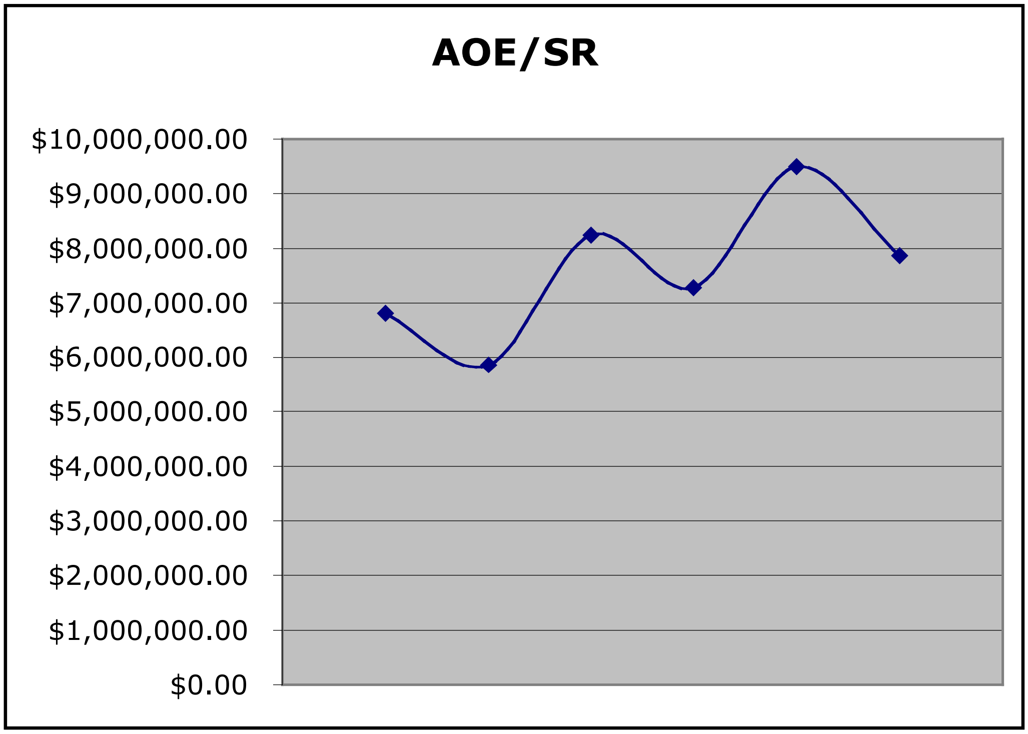

Figure 99. AOE SR Expenditures by Year

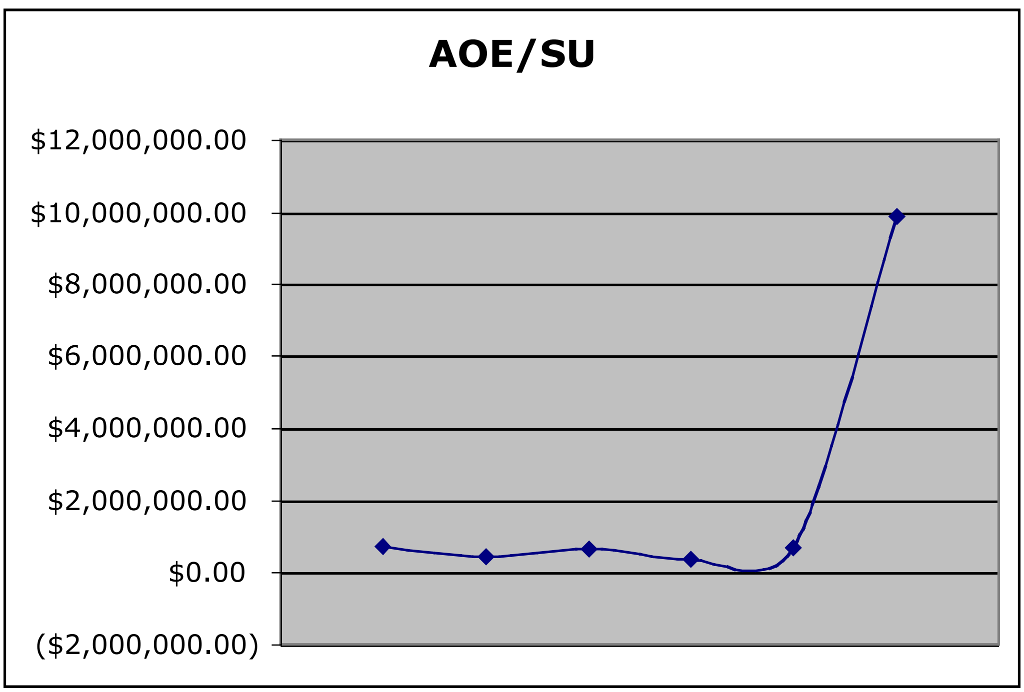

Figure 100. AOE SU Expenditures by Year

APPENDIX F: CORRELATIONS FOR EACH SHIP CLASS

This appendix contains the correlation coefficients for each class of ship. Each table is broken down by cost code and OPTEMPO category, and significant correlations are denoted by an asterisk.

CG	DUW	DNUW	NDUW	NDNUW
CT	0.013745651	0.013745651	0.013745651	0.013745651
SF	0.63593487	0.63593487	0.63593487	0.63593487
SO	0.239498691	0.239498691	0.239498691	0.239498691
SR	0.170827213	0.170827213	0.170827213	0.170827213
SU	-0.214515824	-0.214515824	-0.214515824	-0.214515824

Table 12. CG Correlation Coefficients

DDG	DUW	DNUW	NDUW	NDNUW
CT	0.783678465	0.777819719	0.78360835	0.782576193
SF	0.931150181 *	0.932404181 *	0.931167929 *	0.931421161 *
SO	0.904655654 *	0.910218341 *	0.904726339 *	0.905754815 *
SR	0.949191772 *	0.954271889 *	0.949256631 *	0.950199503 *
SU	0.75918933	0.754673441	0.759135672	0.758344652

Table 13. DDG Correlation Coefficients

FFG	DUW	DNUW	NDUW	NDNUW
CT	-0.291339213	-0.291339213	-0.291339213	-0.291339213
SF	0.019421264	0.019421264	0.019421264	0.019421264
SO	-0.316102452	-0.316102452	-0.316102452	-0.316102452
SR	-0.254192749	-0.254192749	-0.254192749	-0.254192749
SU	-0.056418002	-0.056418002	-0.056418002	-0.056418002

Table 14. FFG Correlation Coefficients

DD	DUW	DNUW	NDUW	NDNUW
CT	-0.629694465	-0.629694465	-0.629694465	-0.629694465
SF	-0.362343263	-0.362343263	-0.362343263	-0.362343263
SO	-0.727864861	-0.727864861	-0.727864861	-0.727864861
SR	-0.837876876	-0.837876876	-0.837876876	-0.837876876
SU	-0.456778059	-0.456778059	-0.456778059	-0.456778059

Table 15. DD Correlation Coefficients

LHA	DUW	DNUW	NDUW	NDNUW
CT	0.539202952	0.539202952	0.539202952	0.539202952
SF	0.480753628	0.480753628	0.480753628	0.480753628
SO	0.397947391	0.397947391	0.397947391	0.397947391
SR	0.552167864	0.552167864	0.552167864	0.552167864
SU	0.524919609	0.524919609	0.524919609	0.524919609

Table 16. LHA Correlation Coefficients

LPD	DUW	DNUW	NDUW	NDNUW
CT	-0.430043274	-0.430043274	-0.430043274	-0.430043274
SF	-0.286062564	-0.286062564	-0.286062564	-0.286062564
SO	0.680040344	0.680040344	0.680040344	0.680040344
SR	-0.272978759	-0.272978759	-0.272978759	-0.272978759
SU	-0.363646672	-0.363646672	-0.363646672	-0.363646672

Table 17. LPD Correlation Coefficients

LSD	DUW	DNUW	NDUW	NDNUW
CT	-0.521557977	-0.281302009	-0.521557977	-0.521557977
SF	0.176870633	0.394237466	0.176870633	0.176870633
SO	0.044064129	0.331327946	0.044064129	0.044064129
SR	-0.492099584	-0.212914957	-0.492099584	-0.492099584
SU	-0.484802302	-0.281539684	-0.484802302	-0.484802302

Table 18. LSD Correlation Coefficients

LHD	DUW	DNUW	NDUW	NDNUW
CT	0.338934661	0.338934661	0.338934661	0.338934661
SF	0.626918533	0.626918533	0.626918533	0.626918533
SO	0.760780044	0.760780044	0.760780044	0.760780044
SR	0.672734536	0.672734536	0.672734536	0.672734536
SU	0.610233473	0.610233473	0.610233473	0.610233473

Table 19. LHD Correlation Coefficients

AOE	DUW	DNUW	NDUW	NDNUW
CT	0.211947096	0.211947096	0.211947096	0.211947096
SF	0.338486586	0.338486586	0.338486586	0.338486586
SO	0.472753132	0.472753132	0.472753132	0.472753132
SR	0.51968404	0.51968404	0.51968404	0.51968404
SU	0.195698081	0.195698081	0.195698081	0.195698081

Table 20. AOE Correlation Coefficients

LIST OF REFERENCES

Bush, G.W. *National Security Strategy of the United States of America*, Washington: GPO, September 2002.

Catalano, J.A. *Toward an OPTAR Allocation Model for Surface Ships of the Pacific Fleet,* Master's Thesis, Naval Postgraduate School, December 1988.

CNO Memo Dtd 10Mar03, *PR-05 Performance/Pricing Model Verification, Validation, and Accreditation*

England, Clark, And Jones *Naval Information Roundup*, Washington: GPO, 2003.

Hascall, Matthews, Gyarmati, Gantt, and Hajdu, *Analysis of the Ship Ops Model's Accuracy in Predicting U.S. Naval Ship Operating Cost*, MBA Professional Report, Naval Postgraduate School, June 2003.

Hosmer L. *Strategic Management*, Prentice-Hall, 1982

Kuker, K.L. and Hanson, D.H. *A Feasibility Study of Relating Surface Ship OPTAR Obligation Patterns to Their Operating Schedules,* Master's Thesis, Naval Postgraduate School, June 1988.

NCAD, *Navy VAMSOC.com*, December 2003, <http://www.navyvamsoc.com>

OMB, *Justification of Estimates for the FY 2004 President's Budget*, Washington: GPO, 2003.

OPNAV, *OPNAV Structure,* September 2003, <http://cno-n6.hq.navy.mil/sites2/opnav.html>

OPNAV, *Defense Planning Guidance (DPG)*, December 2003, <http://cno-n6.hq.navy.mil/n6e/ppbs/ppbsprocess/planning/dpg.htm>

Ting, C. *Estimating Operating and Support Cost Models for U.S. Naval Ships,* Master's Thesis, Naval Postgraduate School, December 1993.

Williams, T.D. *An Analysis of Selected Surface Ship OPTAR Obligation Patterns & Their Dependency on Operating Schedules and Other Factors.* Master's Thesis, Naval Postgraduate School, June 1987.

THIS PAGE INTENTIONALLY LEFT BLANK

BIBLIOGRAPHY

Assistant Secretary of Defense (FM&C) Memo Dtd 31JAN03, *Budget Guidance Memorandum BG 03-1*

Assistant Secretary of the Navy (FM&C) Memo Dtd 31MAR03, *Management Initiative Decision (MID) Number 913, Implementation of a 2-Year Planning, Programming, Budgeting, and Execution (PPB&E) Process*

Bush, G.W. *National Security Strategy of the United States of America*, Washington: GPO, September 2002.

Catalano, J.A. *Toward an OPTAR Allocation Model for Surface Ships of the Pacific Fleet,* Master's Thesis, Naval Postgraduate School, December 1988.

CNO Memo Dtd 05FEB03, *Navy Program Development Procedures for Program Review (PR-05)*

CNO Memo Dtd 10Mar03, *PR-05 Performance/Pricing Model Verification, Validation, and Accreditation*

England, Clark, And Jones *Naval Information Roundup*, Washington: GPO, 2003.

Hascall, Matthews, Gyarmati, Gantt, and Hajdu, *Analysis of the Ship Ops Model's Accuracy in Predicting U.S. Naval Ship Operating Cost*, MBA Professional Report, Naval Postgraduate School, June 2003.

Hosmer L. *Strategic Management*, Prentice-Hall, 1982

Kuker, K.L. and Hanson, D.H. *A Feasibility Study of Relating Surface Ship OPTAR Obligation Patterns to Their Operating Schedules,* Master's Thesis, Naval Postgraduate School, June 1988.

N80 Memo Dtd 04Apr03, *Programming Guidance for PR-05*

NCAD, *Navy VAMSOC.com*, December 2003, <http://www.navyvamsoc.com>

OMB, *Justification of Estimates for the FY 2004 President's Budget*, Washington: GPO, 2003.

OPNAV, *N8 Organization Chart,* December 2003, <https://usco1.hq.navy.mil/n8/webbas01.nsf/(vwWebPage)/webbase.htm?Open-Document&Set=1.Scope=N_8>

OPNAV, *Defense Planning Guidance (DPG)*, December 2003, <http://cno-n6.hq.navy.mil/n6e/ppbs/ppbsprocess/planning/dpg.htm>

Ting, C. *Estimating Operating and Support Cost Models for U.S. Naval Ships,* Master's Thesis, Naval Postgraduate School, December 1993.

Walkenbach, J. *Excel 97 Programming for Windows for Dummies*, IDG Books Worldwide Inc, Foster City CA, 1997

Williams, T.D. *An Analysis of Selected Surface Ship OPTAR Obligation Patterns & Their Dependency on Operating Schedules and Other Factors.* Master's Thesis, Naval Postgraduate School, June 1987.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Fort Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Professor Kenneth Doerr
   Naval Postgraduate School
   Monterey, California

4. CDR Philip Candreva
   Naval Postgraduate School
   Monterey, California

5. Professor John Mutty
   Naval Postgraduate School
   Monterey, California

6. LT Tadd Gorman
   Naval Postgraduate School
   Monterey, California